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THE ATMOSPHERES OF THE PLANETS[1]

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Two ways are open to the retiring president of this association, when he makes what small return he can for the honor of his election. By a sound and time-honored custom, it is his duty and privilege to speak of some topic, within his own technical field, but of general interest. He may therefore either report on his own researches—if he is fortunate enough to have recent or unpublished results good enough to measure up to the standard of a presidential address—or he may survey some section of his part of the field of science in which important gains have lately been made, though his own contribution to this advance may be small. Only the latter course is open to the present speaker: and so, this evening, we may devote a little time to the atmospheres of the planets.

As soon as telescopes became good enough to give a tolerable view of details on the planets, evidence began to accumulate that some of them, at least, possessed atmospheres. Doubtless the first to be noticed were the changes in the markings on Jupiter, which differ radically from one year to the next, and often appear suddenly and last but a few weeks, though thousands of miles in diameter. Only clouds, forming and dissolving in a Jovian atmosphere, can account for such rapid and capricious changes.

Evidence for an atmosphere on Mars is afforded by the polar caps. The steady shrinkage of these during the summer, accompanied by the growth of the opposite cap during the long, cold polar night, is explicable only by the melting or evaporation of deposits of some snow-like substance, which is carried as invisible vapor to the opposite pole, and there deposited. A permanent, non-condensible atmosphere is required for the transport of this vapor.

Venus, when she is considerably nearer to the

[1] Address of the retiring president of the American Association for the Advancement of Science, Pittsburgh, December 31, 1934.

earth than to the sun, shows a crescent phase, like that of the moon, and for the same reason. As she comes more nearly into line between us and the sun, her crescent narrows, and the horns begin to project beyond their normal positions, so that she has been seen as three quarters of a circle, and even as a thin bright ring, with a dark interior. This remarkable phenomenon can be seen only when Venus is within about a degree of the sun, and no chance to observe it again will occur till near the end of the present century; but it has been recorded in the past by several competent observers. Such an extension of the horns—and, above all, the ring-phase—can be explained only as effects of twilight, the illuminated atmosphere of the planet being visible across the narrow dark strip of its surface on the side farther from the sun.

For the three brightest planets, then, the presence of an atmosphere is proved by observation, in three quite different, but equally conclusive ways, all of which were well known to astronomers before the end of the eighteenth century.

Later observations have added evidence of the same type—a few white spots on Saturn, appearing at irregular intervals of some decades, which change shape, shift and disappear as clouds would do; occasional though fugitive clouds, and a measurable effect of twilight, upon Mars; and elusive markings on Venus, which can be photographed only with ultra-violet light, and change greatly between one evening's observations and the next. The extent of atmosphere can also be roughly estimated from the results of direct telescopic observation. The surface details of Jupiter (and of Saturn when any appear) may be seen, and photographed, close up to the limb, despite the very oblique angle of view. It is therefore evident that there can be no such extensive gaseous mantle as veils the earth. At least, there is none above the visible cloud-surfaces of these great planets—how much there may be below is another matter. The rarefied layer which exists, however, suffices to cut down the apparent brightness of the edge of the planets' disks. The effect of contrast against a dark sky conceals this in an ordinary telescopic view; but the first look at one of these planets in strong twilight shows that it is actually of surprising magnitude.

There is more "limb-light" on Mars, and there may be more atmosphere above the visible surface—the real surface, this time; but an atmosphere as thick as the earth's, even if free from clouds or haze, would produce a much greater effect.

For Venus the layer which produces the elongation of the crescent is remarkably thin, rising only about 4,000 feet above the visible surface. But this represents only the part of her atmosphere which is hazy enough to be seen through the glare of our own sky close to the sun. The top of the atmosphere must be much higher; and the bottom, if the visible surface is composed of clouds, much lower, so that its whole amount may be great.

The celestial body which we can observe in far the greatest detail tells quite another story. The moon, viewed telescopically, shows no more atmosphere—whether in the artist's or the physicist's sense—than a bare plaster cast illuminated by a powerful searchlight. Far more delicate tests are possible here than in other instances, and neither refraction nor twilight is present to the minutest degree. Our satellite is naked rock *in vacuo*. Mercury, too, appears to be without an atmosphere, though the evidence is less detailed.

The existence of atmospheres on the majority of the planets—though not on all—is thus established by direct telescopic observation. To determine their composition, we must, as usual, have recourse to the spectroscope: but we meet with two difficulties.

In the first place, many possible atmospheric constituents show no selective absorption whatever in the region accessible to our study. Hydrogen, nitrogen, helium, neon and argon belong in this group, and are hopelessly beyond the reach of our investigation. Secondly, the other gases of the earth's atmosphere absorb too much for our advantage. The worst by far is ozone. Though present in but small amounts, and mainly in the higher layers, it cuts off the whole spectrum short of 2,900 Angstroms, and deprives us of any hope of studying the most interesting parts of all celestial spectra.

Were we working in the infra-red, water-vapor would be almost as troublesome. There are long stretches of the solar spectrum, within the range of present-day plates, in which we can find out little or nothing about the sun's own spectrum. The great wide lines of the water-vapor bands, often overlapping, hide almost everything else. The band near 11,500 A is quite hopeless; that at 18,000 would be worse, if our photographs got so far; one near 9,600 is still very bad; while in those near 8,200 and 7,200 the solar lines can be picked out, with care, among their stronger telluric neighbors.

Oxygen reveals itself by a strong band, with very regularly spaced lines, at λ 7,594 (Fraunhofer's A), the weaker B band near 6,867, and the much fainter α band at 6,277. The terrestrial origin of all these lines is conclusively settled by two tests: first, their changes with the altitude of the sun (varying the air-path) and, for the water-vapor lines, with weather conditions; second, the absence of the Doppler shift, due to the sun's rotation, when light from the east and west limbs is compared. The absence of even faint components of solar origin is explained by the

high temperature, which dissociates such molecules completely.

The intensities of these bands are in inverse order of the abundance of the molecules which produce them —an apparent anomaly, explained by the circumstances of their origin. The ozone band is part of the main system of the O_3 molecule, and, like all such bands, is very intensely absorbed, a layer of the gas, at its worst, being as opaque as one of metal of equal mass per square centimeter. For water-vapor the main absorption bands lie far in the infra-red, and are very strong—those with which we are now concerned involve high harmonics of the fundamental vibrations. The coefficient of absorption, and the intensity of the bands, diminishes rapidly with increasing order of the harmonics and diminishing wavelength.

The oxygen bands are produced by a "forbidden" transition within the molecule, for which the probability of absorption is exceedingly small. This is why the whole mass of oxygen above our heads (equivalent to a layer two kilometers thick at standard temperature and pressure) produces absorption lines no stronger than the sodium vapor in a Bunsen flame an inch thick, which contains but a minute percentage of the vapor of the metal. The principal bands of oxygen, in the ultra-violet beyond λ 1,800, are so strong that light of shorter wave-length can not be observed at all in air. The experimenter must put his whole spectroscope in a gas-tight case, and pump it out to an almost perfect vacuum.

In the visible spectrum, the portions cut out by oxygen or water-vapor are very small in extent; but they come exactly in the wrong place—in other words, they hide, line for line, absorption by these same gases which might be produced in the atmosphere of a planet.

If the planet's atmosphere was decidedly richer in either constituent than the earth's, we might detect the fact, for the lines in the planet's spectrum would be stronger than in that of the moon. Comparisons of this sort, however, must be made with great precautions. The moon and planet must be at the same altitude when the observations are made (to get equal air-paths). It is not safe, either, to observe the planet early in the evening and wait till the moon rises to the same height, for a change in temperature may have caused the precipitation of water out of the air, though the oxygen, of course, remains the same. With sufficient patience, a time may be found when planet and moon can be seen together, at equal altitudes, and observed almost simultaneously, with the same instrument.

Early observations of this sort were supposed to show the presence of oxygen and water-vapor on Venus and Mars; but the careful and accurate work of Campbell, in 1894, led him to the conclusion that there was no perceptible difference in the strength of the bands in the two cases, and hence that the amounts of these two important substances, above the visible surfaces of either planet, did not exceed one fourth of those above an equal area of the earth's.

A more delicate, and very ingenious, test was invented, independently, by two distinguished American observers, Lowell and Campbell. When Mars (or Venus) is approaching us, or receding, most rapidly, the lines in its spectrum are displaced by the Doppler shift, while lines produced in the earth's atmosphere are of course unaffected. Were this shift great enough the planetary and telluric lines would appear double, and the former, even though faint, could readily be detected. The greatest available shift is not enough to resolve the lines completely; but measures of the blended lines suffice to show whether any important planetary contribution is present. A still more delicate test is afforded by microphotometer measures of the contours of the lines, which would reveal even a slight asymmetry. These observations are very exacting—requiring high dispersion and a great deal of light—so that the best evidence is that from the great coudé spectrograph of the 100-inch telescope at Mount Wilson. St. John and Nicholson found, in 1922, that there was no perceptible trace of planetary lines in Venus, and Adams and Dunham, in 1934, have come to the same conclusion in the case of Mars. An amount of oxygen, on either planet, equal to a thousandth part of that above an equal area on earth, could certainly have been detected. For water-vapor, the tests have so far been less delicate, and are not fully decisive—though the quantity present on either planet must be small. More delicate tests, with stronger lines, may soon be made on new red-sensitive plates.

There can be no reasonable doubt, on quite different evidence, that some small amount of water-vapor is actually present in Mars' atmosphere. Radiometric observations of the planet's heat show definitely that the surface rises to temperatures above 0° Centigrade at noon every day in the Martian tropics, and at the pole at midsummer, though falling far below freezing at night. The polar caps must therefore really be composed of snow, and evaporate into water-vapor, even if the pressure is so low that the ice turns directly into vapor without melting. The only plausible alternative suggestion—carbon dioxide—would volatilize at much lower temperatures than the actual polar caps do. But, judging from the amount of solar heat available to evaporate them, the polar caps must be very thin—probably only a few inches

thick. The vapor resulting from the gradual sublimation would never attain any considerable density, and might easily fail of detection by the tests which have so far been practicable.

No such independent evidence is available for Venus, but Adams and Dunham, in 1932, discovered, in the infra-red region of her spectrum, three beautifully defined bands with heads at λ 7,820, λ 7,883 and λ 8,689, and evidently of atmospheric origin. They had not then been observed elsewhere; but an immediate suggestion regarding their origin was obtained from the theory of band-spectra—by that time well developed. The spacing of the individual lines in a band arises from the rotation of the molecule and depends upon its moment of inertia. For the new planetary band, it showed that the otherwise unknown molecule involved must have a moment of inertia of 70.5×10^{-40} c. g. s. units. This agreed almost exactly with that of the molecule of carbon dioxide—already known from laboratory observations in the infra-red. All doubt regarding this identification was removed when Dunham, passing light through 40 meters of CO_2 at a pressure of 10 atmospheres, found that the strongest of the bands found in Venus was faintly absorbed. Recently Adel and Slipher, using a path of 45 meters through gas at 47 atmospheres' pressure, have found the bands considerably weaker than they appear in the planet. They conclude that the amount of carbon dioxide above the visible surface of Venus is at least two mile-atmospheres—that is equivalent to a layer two miles thick at standard atmospheric pressure and temperature. The whole amount above the planet's solid crust may be much greater. For comparison it may be noted that the whole atmosphere of the earth amounts to five mile-atmospheres, and the oxygen in it to one and a quarter.

These bands do not show in the solar spectrum, even when the sun is setting. But there is very little CO_2 in the earth's atmosphere, and the whole amount in the path, even at sunset, amounts to only thirty feet under standard conditions.

The weak absorption in these bands, like that in the visible bands of water-vapor, arises because they involve high harmonics of the fundamental vibration-frequencies—in this case the fifth.

So far we have had to do with bands of familiar and readily identified molecules; but the major planets have been much more puzzling.

Jupiter shows a conspicuous band in the orange, which was discovered visually by Huggins in the earliest days of spectroscopy, and fainter ones in the green. These appear more strongly in Saturn, but only in the spectrum of the ball of the planet, and not at all in that of the ring—which might be anticipated, since the ring consists of a multitude of tiny isolated satellites, and should be quite devoid of atmosphere. Uranus, though its light is faint, shows the same bands, much more strongly, and many others in addition. One of these, which closely coincides with the F line of hydrogen (λ 4,861) led Huggins to conclude that the planet's atmosphere was rich in hydrogen.

This interpretation, though quite permissible at the time, was erroneous, for the line is absorbed only by dissociated *atoms* of hydrogen, which will not be present except at very high temperatures.

The bands cut out so much of the red and orange light that the whole disk of Uranus appears decidedly green—an unusual color, noticed from the time of the planet's discovery.

In Neptune's spectrum, the bands are of enormous strength, cutting out the red almost entirely and making the planet look still greener. They are hard to observe visually in so faint an object, and the full realization of their intensity came only with the admirable photographs of V. M. Slipher, in 1907. In later years, and with modern plates, Slipher has extended his observations far into the red, finding bands of ever-increasing strength—up to λ 10,000 for Jupiter, where there is light enough to follow the spectrum farthest.

For more than sixty years after their first discovery, and twenty-five after Slipher's spectrograms, these bands presented one of the principal unsolved puzzles of spectroscopy—for no one had duplicated them in the laboratory. To be sure, one group, near λ 7,200, agrees fairly well with a band of water-vapor—but the still stronger water-bands deeper in the red are absent, so that this must be a chance coincidence.

When the radiometric measures of Coblentz and Lampland, and of Nicholson and Pettit, showed that the temperature of the visible surfaces of Jupiter and Saturn must be well below $-100°$ Centigrade—while Uranus and Neptune are doubtless colder—the range of possibilities was very much narrowed. But it was not until 1932 that a young and brilliant German physicist, Rupert Wildt, realized the solution of the problem.

Other gases, like water-vapor and carbon dioxide, have strong fundamental absorptions in the infra-red, and fainter harmonics in the more accessible part of the spectrum, which demand a long absorbing path in the laboratory to bring them out. Utilizing observations of this sort, Wildt showed that certain bands in the spectrum of Jupiter near λ 6,470 and λ 7,920 agreed with those of ammonia, and others, at λ 6,190, λ 7,260 and λ 8,860, with bands of methane. The original comparison was not quite conclusive, for with the moderate dispersion then employed the planetary bands had not been adequately

resolved into their component lines. This was soon accomplished by Dunham, who found so complete a coincidence of the accurately measured individual lines that both identifications were put beyond all question. For ammonia more than sixty lines were found to agree, and for methane 18 lines in part of one band. Some expected band lines were naturally blended with solar lines, but not one of importance failed to appear.

From these comparisons Dunham estimates that the quantity of ammonia gas above the visible surface of Jupiter is equivalent to a layer ten meters thick under standard conditions. In Saturn it is less.

The climax of the tale came this year, when Adel and Slipher announced that practically all the bands had been identified, and were due to methane. The 45-meter path and the 40-atmosphere pressure got enough of the gas into the way of the light to produce bands intermediate in intensity between those in Jupiter and in Saturn. At this high pressure the lines flowed together, and produced diffuse bands; but the agreement of these with the planetary bands was so complete as to be decisive.

A further, and wholly conclusive, test could be added. The fundamental frequencies of vibration of the methane molecule were already known, from observations in the infra-red. For the higher harmonics of these vibrations the frequencies are not exact multiples of the lowest, but nevertheless bear a simple numerical relation to them (as is well known in the case of other gases). Applying this test, the strongest bands (including Huggins' band in the orange, and the one coincident with the blue hydrogen line) were found to be harmonics, from the third to the eighth, of one of the fundamental frequencies, while another slower vibration was represented by all its harmonics from the eighth to the sixteenth. The remaining bands were accounted for by combinations of these harmonics with other known frequencies, all of types consistent with the well-established rules which govern band spectra. Thirty-six bands in all have been identified. Many of these appear only in Uranus and Neptune, and have not yet been produced in the laboratory, but the harmonic relations just mentioned make their identification certain. The higher gaseous hydrocarbons, ethane, ethylene and acetylene, all have bands in places clear of disturbance by the methane; and all were looked for in vain. All the planetary bands of any importance are accounted for by methane alone—it is a clean sweep.

From the published data, it appears that the amount of methane above the visible surface of Jupiter is of the order of one mile-atmosphere. There must be much more on Uranus, and especially on Neptune; but we can not yet estimate its amount.

There is still plenty of work to do upon these bands, but mainly for the theoretical investigator. Adel calculates that the band at λ 5,430, when fully resolved, should consist of eighteen different overlapping systems of many lines each. Fortunately, the astrophysicist need not wait to draw his conclusions till this has been completely analyzed.

The results of observation can be summarized in a sentence. Large planets have atmospheres containing hydrogen compounds; middle-sized planets, atmospheres containing oxygen compounds; and small planets no atmospheres at all. The reason, in the last case, was found by Johnstone Stoney, in 1897. It is simply that small bodies have not sufficient gravitative power to keep their atmospheres from diffusing away into the vacuum of interplanetary space. At the surface of any planet, there is a certain velocity of escape, depending only on its mass and radius. A body projected from its surface, in whatever direction, with this or any higher velocity, will fly off in a parabolic or hyperbolic orbit and never return—unless, indeed, it meets with some obstacle or resistance on its outward way. For the moon this velocity is 2.4 kilometers per second; for the earth, 11.2; for Jupiter, 60.

Now the molecules of any gas are continually flying about in all directions, with average speeds which depend upon their weights. At zero Centigrade the average speed for a hydrogen molecule is 1.84 km/sec; for oxygen, 0.46; for carbon dioxide, 0.39. If an atmosphere of hydrogen could be put upon the moon, every molecule that was moving but a little faster than the average would fly off at once into space, unless it was thrown back by collision with another, and the atmosphere would diffuse away in a very short time. With an escape velocity three times the average speed, enough fast-moving molecules would get away to reduce the atmosphere to half its original amount in a few weeks (according to Jeans). The rate of loss falls off very rapidly beyond this, so that, with an average velocity one fifth that of escape, the atmosphere would remain for hundreds of millions of years.

The moon's surface reaches a temperature exceeding 100° C. during every rotation, and it follows that neither air nor water-vapor could permanently remain above its surface. If at any time in its past history, it has been really hot, like molten lava, it could have retained no trace of atmosphere. For Mercury, the escape velocity is half as great again as for the moon; but the planet, being so near the sun, is much hotter, and it, too, can not retain an atmosphere. Mars, with an escape velocity of 5 km/sec, could not hold hydrogen but should retain water-vapor—as it appears to have done—and all heavier gases. Venus and the earth, at their present

temperatures, should retain even hydrogen, and the major planets would do so even if incandescent.

This reasoning explains the cases of Mercury and the moon, and leads to the important conclusion that all smaller bodies, such as the asteroids and satellites, must be wholly devoid of atmosphere—except perhaps bodies like Neptune's satellite, which is relatively massive, and must be very cold. We can not be sure about Pluto, for we know neither its size nor its mass; but it is probable that, at most, it may have a thin atmosphere, like Mars.

The same principle was invoked, shortly after its discovery, to explain the great difference in mean density between the major and the terrestrial planets. The moon, Mercury, Mars, Venus and the earth all have densities between 3.3 and 5.5 times that of water. The rest are almost certainly what we know the earth to be, spheroids of rock, with cores of metallic iron of varying sizes. For the major planets, the densities range from 1.6 for Neptune to 0.7 for Saturn. Moulton suggested, about 1900, that they contained great quantities of light substances, which the smaller terrestrial planets had not been able to keep from diffusing away into space. This has been fully confirmed by later studies.

From the ellipticity of a planet and the changes in its satellites' orbits caused by the attraction of its equatorial bulge, information may be obtained regarding the degree to which the density increases toward its center. Applying this to Jupiter and Saturn, Jeffreys concludes that they contain cores of rock and metal, like the inner planets, surrounded by vast shells of ice—frozen oceans thousands of miles deep—and above this, again, atmospheres of great extent. Throughout most of the atmospheres, the pressure must be so great that the gas is reduced to a density as great as it would have if liquefied, or even solidified, by cooling. Indeed, Wildt believes that the enormous pressure would actually solidify even the "permanent" gases.

Now this outer layer is of low density—less than 0.78 for Jupiter and 0.41 for Saturn—according to Wildt's calculations. This excludes all but a few possible constituents. Frozen oxygen has a density of 1.45, nitrogen 1.02, ammonia 0.82. Only hydrocarbons (methane 0.42, ethane 0.55), helium (0.19) and hydrogen (0.08) come within the limits even for Jupiter. We can therefore conclude, from considerations of density alone, that the outer parts of Jupiter probably, and of Saturn certainly, contain great quantities of free hydrogen or helium. Uranus and Neptune are similar to Jupiter.

It is generally believed that the planets have been produced, in some way or other, from matter ejected or removed from the sun. No really satisfactory theory of the process of formation has yet been devised; but no other hypothesis has yet done better, and the isolation of the sun and planets in space makes a common origin highly probable.

Now we know the composition of the sun—at least of its outer layers—much better than we do that of the planets. Quantitative spectroscopic analysis, though still beset with difficulties, has advanced far enough to show that most of the sun's outer layers is composed of hydrogen; next come helium, oxygen and carbon, followed by nitrogen, then silicon and the metals. A mass of matter removed from the sun and allowed to cool without serious loss would therefore closely resemble the major planets. If small enough to lose all its atmosphere, it would be like the moon or the asteroids—though there are difficulties in seeing how such small masses could have escaped diffusing away altogether before the more refractory constituents solidified.

The history of a body of intermediate mass is more interesting. Hydrogen and helium would be lost while it was still very hot. So would most of the other light gases such as neon and nitrogen (which at the temperature even of the sun's surface is dissociated into atoms). Free oxygen, too, would escape, but a good deal might be retained in combination with silicon and the metals. As the gaseous mass cooled, by expansion and radiation, drops of molten metal and lava would form within it, as Jeffreys suggests, and fall toward the center, building up a molten core. After the first turbulence was over, there would remain a molten planet surrounded by an atmosphere containing heavy inert gases, such as argon, perhaps some carbon dioxide, and as much of the nitrogen and neon as had failed to escape. Menzel and I, a few years ago, noticed that neon, while apparently fully as abundant in the stars and nebulae as argon, is but 1/500 as abundant in the earth's atmosphere; while nitrogen, which is cosmically an abundant element, showing strong spectral lines, forms but a very small portion of the earth's mass. It appears, therefore, that a mass of the earth's magnitude must have lost almost, though not quite, the whole of its primitive atmosphere.

Still following Jeffreys, it appears that, as the molten earth cooled, the two-thousand-mile deep sea of lava solidified first at the bottom (where the melting point was greatly raised by pressure) and so gradually to the surface. During this process great quantities of gases, mainly water-vapor, must have been evolved from the solidifying magma, and escaped to the surface, forming a new atmosphere which now would not escape, since the surface was cooler. With solidification would come rapid superficial cooling, and an ocean would bathe the rocky crust, leaving an atmosphere of moderate extent. Carbon dioxide—evolved from the magma, and per-

haps partly primitive—would be a major constituent, along with nitrogen, argon, neon and other minor left-overs. The presence of free oxygen seems very unlikely, for practically all volcanic rocks and gases are unsaturated with respect to this element—the former containing much ferrous iron and the latter being often actually combustible when they meet the air.

The present rich supply of oxygen appears to be a by-product of terrestrial life. (This suggestion is more than a century old.) The earth, indeed, may be regarded as an intensively vegetated planet, from whose atmosphere the greedy plants extract the remaining residue of carbon dioxide so rapidly that if it were not returned to the air by combustion, respiration and decay, the whole supply would be exhausted in a decade or so. Oxygen removed from the atmosphere by these processes is speedily returned by plants; but there is another process of slow depletion which is irreversible. During rock-weathering, about half the ferrous iron of the rocks is oxidized to the ferric state. Goldschmidt (from whose admirable geochemical papers the present discussion is borrowed) concludes that the amount of "fossil" oxygen thus buried in the sedimentary rocks is at least as great as that now present in the atmosphere and may be twice as great. An amount of carbonaceous or other organically reduced material equivalent to both the free and the fossil oxygen must also be in the sediments—which is not unreasonable. Given time enough, this inexorable process of rock-decay might exhaust the remaining oxygen of our atmosphere and put an end to all that breathes. But this danger is indefinitely remote—a billion years away anyhow, since life has lasted that long and only half the oxygen has been used up; and probably much longer, for volcanic gases are still carrying "juvenile" carbon dioxide into the air that has never been there before.

It is of no small interest, however, to look at Mars and see there what looks very like the end of this process. The reddish color of the planet—unique among the heavenly bodies—is just what might be expected, and indeed is almost inevitable in a surface stained with ferric compounds. (The unoxidized rocks of the moon are gray or, at most, brownish.) Wildt suggests that, in the thin atmosphere of Mars, the ozonized layer produced by the action of ultraviolet light at the top of the atmosphere should be near the surface—not high up, as it is here—and that oxidation processes at the planet's surface might thus be accelerated.

It would be premature, however, to conclude that Mars must be a lifeless planet. The depletion of oxygen would be very slow, and plant life would probably adjust itself, as it has done on the earth in response to far more rapid climatic changes. Whether animal life, if ever present, could have survived, is speculation. A race of no more intelligence and engineering skill than our own could presumably meet the situation and survive in diminished numbers breathing electrolytic oxygen—provided that it paid any attention to changes so slow as to be imperceptible in a thousand generations!

While Mars resembles the final stage of our suggested process, Venus seems to be at the beginning, and much like what a lifeless earth would be. We do not know how life began here, but conditions may well have been much less favorable on Venus. Wildt concludes that the powerful "blanketing" effect of the atmospheric CO_2, combined with the stronger solar radiation, may raise the temperature at the planet's actual surface to 100° C. or higher—in which case the failure of life to develop is not surprising. The real puzzle is the apparent absence of water on Venus' surface. She is almost a twin of the earth in size, mass, density, and so on, and one might have expected an ocean of comparable volume. Wildt suggests that all the water has gone into hydrated minerals; but how this could happen unless there was much less there originally than on earth is hard to understand.

For the major planets we have to consider the course of events in a cooling mass containing an excess of the lighter elements and especially of hydrogen. The condensation of the refractory constituents should take place much as for a smaller body. The principal constituents of the rocks, however—potassium, sodium, magnesium, aluminium, calcium and silicon—are not reduced from their oxides by hydrogen, and would form rocks not unlike those of the earth. But at high temperatures the oxides of iron are reduced by hydrogen. My colleague, Professor H. S. Taylor—to whom I am greatly indebted for counsel on these problems of physical chemistry—remarks that the drops of molten lava falling through a hydrogen atmosphere reproduce pretty closely the conditions of a blast furnace. We may conclude then that most of the iron would go into the core and less into the rocky shell.

After the core solidifies, the remainder of the mass will remain fluid over a wide range of temperature. Its principal elementary constituents will be hydrogen, helium, oxygen, carbon and nitrogen, with smaller quantities of the other inert gases, sulfur and the halogens.

The principal reactions which occur in such a gaseous medium at different temperatures and pressures have been carefully studied, for, in addition to their theoretical interest, they are of great practical importance in chemical industry.

When oxygen, carbon and hydrogen are considered the main reaction is

$$CO_2 + 4H_2 \leftrightarrows CH_4 + 2H_2O$$

The formation of methane is accompanied by diminution of volume: hence it will be favored by high pressure. High temperature works the other way: from the free-energy data it appears that, at 1000° C. and atmospheric pressure, the equilibrium inclines to the side of carbon dioxide, even in the presence of a large excess of hydrogen. Below 300° C. practically all the carbon should go into methane: at about 600° the amounts of the two gases should be comparable.

With hydrogen and higher hydrocarbons the tendency of the reaction is always towards methane at low temperatures. With saturated hydrocarbons, this involves no change of volume and should not be affected by pressure. Formation of methane from unsaturated hydrocarbons should be favored by high pressure. The exclusive presence of methane in the planets' atmospheres might thus have been predicted.

The formation of ammonia from its elements, in accordance with the equation

$$N_2 + 3H_2 \rightleftarrows 2NH_3$$

liberates less energy. With excess of hydrogen, and at atmospheric pressure, the amounts of nitrogen and ammonia should be equal between 200° and 300° C., ammonia should predominate at lower temperatures and at higher pressures.

The oxides of nitrogen are endothermic and so would tend to dissociate, rather than to form.

We may now form a definite picture of the successive reactions which will occur in the atmosphere of a cooling major planet. At temperatures of about 1000° the predominant hydrogen will be mixed with steam, free nitrogen and carbon dioxide—the carbon monoxide which occurs in stellar atmospheres having long ago been completely oxidized. With falling temperature the carbon dioxide will be converted into methane before the water reaches its critical temperature and begins to condense. After most of it has been precipitated, the nitrogen will go over into ammonia. These reactions, however, will run their course at these relatively low temperatures only with appropriate activation. For the formation of methane an excellent catalyst is available in the partially reduced oxides of iron which should be present on the rocky surface exposed to hot hydrogen. These would be equally good for the ammonia, but they may be at the bottom of the sea by the time the proper temperature is reached. An adequate activation, however, would be furnished by electrical discharges—and, if terrestrial thunderstorms are any guide, these should be abundant so long as vapors arising from the hot ocean are being condensed. When the temperature has fallen to that which the earth at present enjoys, there will be an extensive atmosphere of hydrogen, mixed with the simple hydrides—methane, ammonia and water-vapor, along with any inert gases which may all along have been present, but with little or no free nitrogen or carbon dioxide. Below this will be an ocean—perhaps very deep, strongly alkaline with ammonia, and incidentally containing in solution any compounds of sulfur and the halogens which may originally have been present. The conditions in such an alkaline ocean—its action on the rocky bed, the compounds which it will hold in solution, and the deposits which it may form—would be of great interest, but are outside our present scope.

With further cooling the water will freeze, but at a temperature below 0° C. depending on the percentage of ammonia. With one part of the latter to two of water the freezing point would drop to −100° C., but it is doubtful if there is enough ammonia for this. The major planets—even Jupiter—are still colder, and the water must be thoroughly frozen out of their atmospheres, leaving only ammonia and methane. The ammonia, indeed, must be at the point of precipitation. Dunham has obtained in this way a minimum temperature for Jupiter's visible surface. The ten meters of ammonia above the surface, under the planet's surface gravity, should exert a pressure of 1.5 mm (on the familiar laboratory scale). The vapor tension of the solid (below the triple point) has this value at −107° C. At a lower temperature the observed quantity of ammonia could not exist in the atmosphere—it would partially condense itself by its own weight.

If the atmosphere consists mainly of hydrogen this limit may be lower, for the mean molecular weight is diminished, and the partial pressure of the ammonia in the same proportion. With a large excess of hydrogen the pressure may be reduced to one sixth of the previous value and the limiting temperature to −120° C.

The direct radiometric observations of Jupiter indicate a temperature of about −135°; but this determination is complicated by large and rather uncertain corrections for the absorption of infra-red radiation in the atmospheres of the earth and the planet, so that the agreement is about as good as could be expected. It is, therefore, very probable that the clouds which form Jupiter's surface are composed of minute crystals of frozen ammonia. A perfectly absorbing and radiating planet, at Jupiter's distance and heated exclusively by the sun, would have a mean temperature of −151° C. The excess in the actual temperature may be attributed partly to the fact that we observe the sunlit (and warmer) side; partly to the "greenhouse" effect of the atmosphere, which lets in the short-wave radiation from the sun much more

easily than it lets the long-waves emitted from the planet's surface out again; and partly, perhaps, to some residual internal heat in the planet. The existence of the latter is made probable by the rapid changes in the cloud-forms, which often suggest the ascent of new material from below. The variety of colors upon the surface, which range from clear white through pinks and browns almost to black, remain unexplained.

On Saturn, where the ammonia bands are fainter than on Jupiter and the surface gravity less than half as great, the limiting temperature may be 10° or 15° lower. The radiometric observations indicate about the same difference.

Uranus and Neptune, being farther from the sun, should be still colder. The ammonia should be frozen out of their atmospheres, leaving them clear to a greater depth, which may explain the extraordinary strength of the methane bands in their spectra. The methane itself must be nearly ready to condense on Neptune, despite its very low boiling point. Assuming, roughly, that Neptune has six mile-atmospheres of methane above its surface, the pressure, due to this alone, would be about 500 mm and the limiting temperature $-165°$ C. A large excess of hydrogen might reduce this to $-183°$. Solar radiation alone would maintain a mean temperature near $-220°$. Whether the difference arises from the powerful "greenhouse" effect of the methane itself, or from internal heat, can not yet be determined. It may be, however, that if the methane could once be frozen out of Neptune's atmosphere, the surface temperature would fall so much that it would stay frozen and leave the planet with an atmosphere which, apart from the inevitable Rayleigh scattering, exerted no influence upon visible light.

The problem of planetary atmospheres, so perplexing a few years ago, is now far advanced toward its solution. Toward its interpretation many of the sciences have contributed—astronomy, physics, chemistry, geology, biology and technology. No one of them alone could have resolved the difficulties. It may, therefore, be appropriate that the attention of so general a scientific gathering may have been invited for a while to it: for it truly illustrates the old motto, "In union there is strength."

SCIENTIFIC EVENTS

THE BRITISH WATER POLLUTION RESEARCH BOARD

IN the annual report of the Water Pollution Research Board for the year ended June 30, 1934, issued by the Department of Scientific and Industrial Research, according to a summary in the London *Times*, reference is made to the exceptional conditions of weather during 1933 and 1934. The long spell of dry weather not only caused difficulties in the provision of ample quantities of water, but also had a serious detrimental effect on the quality of the water in rivers and streams into which sewage and trade effluents are discharged, as less water than usual was available for dilution of the discharges.

The investigations initiated by the board may be divided into four main groups dealing respectively with purification of water for public supply, methods of treatment and disposal of sewage, methods of treatment and disposal of trade effluents, and various problems of river pollution.

With regard to water for public supply, many experiments have been carried out with the object of ascertaining the effects of various factors on the treatment of water by the base-exchange process of softening. During the last two years experiments have been carried out on methods of treatment of British clays with the object of preparing base-exchange material suitable for water softening. Many samples of clays have been employed and a method of treatment has been devised whereby prepared clays have been produced with water-softening capacities greater than those of some imported materials at present in use.

Further experiments have been carried out in the laboratory on methods of treatment of the waste waters discharged from dairies and milk products factories. These effluents may seriously affect rivers and streams into which they are discharged, and may be many times as strong in polluting character as domestic sewage. The problem is of particular importance at the present time because of the expansion of the milk industry and the increase in the number of large centralized factories and milk collecting and distributing depôts. During the year many cases of serious difficulty and pollution of streams by such effluents have arisen. The experiments have indicated that there are methods whereby the effluent can be satisfactorily purified before disposal, and a stage has been reached at which the processes suggested should be tested on a large scale. The industry has been informed of the progress of the work and has been offered the opportunity of cooperating both technically and financially in the further investigations which are desirable.

Considerable progress has been made in fundamental investigations of the biology and chemistry of methods of purification of sewage.

The question has also arisen whether the amount

of material deposited and the character of the deposits in the estuary of the River Mersey and in Liverpool Bay are affected by the large quantities of sewage discharged into the estuary of adjacent towns. In response to a request from the Merseyside local authorities, the Mersey Docks and Harbor Board, and other interested bodies, a comprehensive investigation of the subject has been undertaken.

THE ANNUAL REPORT OF THE DIRECTOR OF THE FIELD MUSEUM OF NATURAL HISTORY

Still operating on a very much curtailed budget, necessitated by depression, the Field Museum of Natural History nevertheless was able to maintain during 1934 full activity so far as services to the public are concerned, according to the annual report of Dr. Stephen C. Simms, director of the museum.

Attendance at the museum was more than 1,985,000 persons. While this was a decline of about 1,284,000 from the 3,269,390 visitors received during 1933, it was nevertheless the second highest year's attendance in the history of the museum, and the reduction from the 1933 peak was a natural expectation in view of the smaller attendance at the second year's Century of Progress Exposition. Of the visitors in 1934, only about 99,000, or approximately 5 per cent., paid the 25-cent admission fee charged on certain days; all the rest, approximately 95 per cent., either went on the days when admission is free, or belonged to classifications such as children, teachers and students, who are admitted free on all days.

The scientific expeditions of the museum had to be kept to a minimum. The Straus West African Expedition of Field Museum, sponsored by Mrs. Oscar Straus, of New York, collected zoological material in Senegal, the French Sudan, Nigeria and Angola (Portuguese West Africa). The Leon Mandel Guatemala Expedition, sponsored by Leon Mandel, of Chicago, concluded its work of making comprehensive collections of characteristic Central American fauna. Research on sites of ancient Maya civilization was conducted by an expedition jointly sponsored by the Carnegie Institution of Washington, D. C., and Field Museum. The Field Museum Archeological Expedition to the Southwest, financed by the Julius and Augusta N. Rosenwald Fund of the museum, carried on its fourth season of operations on the Lowry ruin, prehistoric Indian site in Colorado. An anthropometric survey of Kurd, Arab and Beduin populations was made by the Anthropological Expedition to the Near East sponsored by Marshall Field, of New York and Chicago. The Joint Botanical Project of the Rockefeller Foundation and Field Museum was in its fifth year of operations in Europe. Paleontological field work was conducted in Nebraska, the Bad Lands of South Dakota and Pennsylvania.

A new hall devoted to domestic animals was opened. It contains a series of sculpture in marble and bronze, one fourth life-size, by the sculptor Herbert Haseltine, of champion horses, beef and dairy animals, sheep and swine of Great Britain. The collection is a gift to the museum from Marshall Field, a member of the board of trustees. Many new habitat groups of wild animals were added to the zoological exhibits. The additions of further sculptures of types of races of mankind by Malvina Hoffman brought the series of nearly 100 figures in Chauncey Keep Memorial Hall practically to completion.

The regular lecture courses in spring and autumn, and the year-around lecture tours for adults, as well as the series of motion picture programs, extension lectures and other activities for children presented by the museum unit known as the James Nelson and Anna Louise Raymond Foundation, were continued as in other years, and were attended by approximately 240,000 persons. The N. W. Harris Public School extension, another separately endowed department of the museum, maintained its service of circulating some 1,300 traveling natural history exhibits which daily reach about 500,000 children in all the public and many private schools of Chicago.

Field Museum Press issued a number of important scientific publications for international circulation, as well as several leaflets in popular style for lay readers.

Two new members were elected to the museum's board of trustees—Joseph N. Field, of Chicago, and Leslie Wheeler, of Lake Forest, Ill. The museum suffered the loss by death of its curator of anthropology, Dr. Berthold Laufer, noted for his research in Oriental subjects. Subsequent to his death, Dr. Paul S. Martin was appointed acting curator in charge of the department.

OFFICERS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

A full account of the Pittsburgh meeting of the American Association for the Advancement of Science and of the scientific societies associated with it, edited by the permanent secretary, will be published in the issue of Science for February 1.

Officers of the association were elected as follows:

President

Dr. Karl T. Compton, president of the Massachusetts Institute of Technology.

Vice-Presidents and Chairmen of the Sections

Mathematics—Dr. T. H. Hildebrandt, University of Michigan.

Physics—Dr. John T. Tate, University of Minnesota.

Chemistry—Dr. Moses Gomberg, University of Michigan.

Astronomy—Dr. H. R. Morgan, U. S. Naval Observatory.

Geology and Geography—Dr. Walter E. McCourt, Washington University.

Zoological Sciences—Dr. Oscar Riddle, Station for Experimental Evolution, Carnegie Institution of Washington, Cold Spring Harbor, L. I.

Botanical Sciences—Dr. E. W. Sinnott, Columbia University.

Anthropology—Dr. N. C. Nelson, American Museum of Natural History, New York.

Psychology—Dr. Joseph Peterson, George Peabody College for Teachers, Nashville, Tenn.

Social and Economic Sciences—Dr. Shelby Harrison, Russell Sage Foundation, New York.

Historical and Philological Sciences—Dr. George Sarton, Harvard College Library.

Engineering—Dr. Harvey N. Davis, president, Stevens Institute of Technology, Hoboken, N. J.

Medical Sciences—Dr. Stanhope Bayne-Jones, Yale University Medical School.

Agriculture—Dr. H. K. Hayes, University of Minnesota.

Education—Dr. F. B. Knight, University of Iowa.

GENERAL SECRETARY

Dr. Otis W. Caldwell, professor of education and director of the Institute of School Experimentation, Teachers College, Columbia University.

MEMBERS OF THE EXECUTIVE COMMITTEE

Dr. Burton E. Livingston, director of the laboratory of plant physiology, the Johns Hopkins University.

Dr. J. McKeen Cattell, editor of SCIENCE.

MEMBERS OF THE COUNCIL

Dr. Louis B. Wilson, professor of pathology and director of the Mayo Foundation.

Dr. William F. Ogburn, professor of sociology, University of Chicago.

MEMBERS OF THE COMMITTEE ON GRANTS

Roger Adams, University of Illinois.

McKeen Cattell, Cornell University Medical College.

MEMBER OF THE FINANCE COMMITTEE

Dr. Herbert A. Gill, Washington, D. C.

TRUSTEE OF SCIENCE SERVICE

Dr. Henry B. Ward, permanent secretary of the American Association for the Advancement of Science.

MEMBER OF THE DIVISION OF FOREIGN RELATIONS OF THE NATIONAL RESEARCH COUNCIL

Dr. William A. Noyes, professor of chemistry and emeritus director of the chemical laboratory, University of Illinois.

SECTION COMMITTEEMEN

Mathematics (A)—E. B. Stouffer, University of Kansas.

Physics (B)—A. L. Hughes, Washington University.

Chemistry (C)—J. H. Hildebrandt, University of California.

Astronomy (D)—Dinsmore Alter, University of Kansas.

Geology and Geography (E)—Edward L. Troxell, Trinity College, Hartford, Conn.

Zoological Sciences (F)—Paul S. Welch, University of Michigan.

Botanical Sciences (G)—F. E. Denny, Boyce Thompson Institute.

Anthropology (H)—Truman Michelson, Smithsonian Institution, Washington, D. C.

Psychology (I)—John Dashiell, University of North Carolina.

Historical and Philological Sciences (L)—John W. Oliver, University of Pittsburgh, and M. J. Herskovits, Northwestern University.

Engineering (M)—C. J. Tilden, Yale University.

Medical Sciences (N)—Walter W. Cannon, Harvard Medical College.

Agriculture (O)—Emil Truog, University of Wisconsin.

Education (Q)—A. I. Gates, Columbia University.

RECENT DEATHS

DR. G. CARL HUBER, professor of anatomy, director of the anatomical laboratories and dean of the Graduate School of the University of Michigan, died on December 26. He was sixty-nine years old and had been a member of the faculty for forty-five years.

DR. FRANK THILLY, professor of philosophy at Cornell University since 1906 and from 1915 to 1921 dean of the College of Arts and Sciences, died on December 28, at the age of sixty-nine years. Dr. Thilly was from 1891 to 1893 fellow and instructor in logic and the history of philosophy at Cornell, resigning to become professor of philosophy at the University of Missouri. In 1904 he was called to Princeton University, where he was Stuart professor of psychology for two years, returning to Cornell in 1906.

DR. LEWIS STEPHEN PILCHER, from 1885 to 1895 professor of surgery at the New York Post-Graduate Medical School; founder and former editor of the *Annals of Surgery*, died on December 24. He was eighty-nine years old.

CAPTAIN JOSEPH E. BERNIER, the French-Canadian Arctic explorer, died on December 26. He was eighty-three years old.

DR. GEORG ELIAS MÜLLER, professor of philosophy at the University of Göttingen since 1881, died on December 27. He was eighty-four years old.

A CORRESPONDENT writes: "Professor Wilhelm His, for many years the head of the first medical clinic of the Berlin Charity Hospital, died on November 10 at the age of seventy-one years, in Brombach, where he had been living in retirement since 1932. He was the son of the well-known anatomist of the same name. The younger His is known for his discovery of the His's Bundle and for the His's Disease or Five-day Fever which made its appearance during the war."

SCIENTIFIC NOTES AND NEWS

PROFESSOR EDWARD BARTOW, head of the department of chemistry and chemical engineering in the State University of Iowa, has been elected president of the American Chemical Society for 1936. He will serve as president-elect during 1935. On January 1, Professor Roger Adams, of the University of Illinois, now president-elect, took office as president of the society, succeeding Dr. Charles L. Reese, retired chemical director of E. I. du Pont de Nemours and Company, Inc.

DR. NEVIN M. FENNEMAN, professor of geology and geography at the University of Cincinnati, was elected president of the Geological Society of America at the recent meeting at Rochester, New York.

DR. CLARENCE S. ROSS, geologist of the U. S. Geological Survey, was elected president of the Mineralogical Society of America, and Dr. Charles K. Swartz, who retired in 1931 as collegiate professor of geology at the Johns Hopkins University, was elected president of the Paleontological Society.

DR. K. F. MEYER, professor of bacteriology and director of the Hooper Foundation for Medical Research of the University of California, has been nominated for election to the presidency of the Society of American Bacteriologists.

OFFICERS of the American Society of Tropical Medicine were elected at its thirtieth annual session in San Antonio on November 14, 15 and 16 as follows: Dr. Edward B. Vedder, of the medical research laboratory of the Chemical Warfare Service, Edgewood Arsenal, *president;* Dr. Henry E. Meleney, associate professor of preventive medicine at Vanderbilt University, *president-elect;* Dr. Lewis W. Hackett, assistant director of the International Health Division of the Rockefeller Foundation, *vice-president,* and Dr. Chas. F. Craig, professor of tropical medicine and director of the department, at the School of Medicine, of Tulane University, *editor.* Dr. Alfred C. Reed, of the Pacific Institute of Tropical Medicine at the University of California, is secretary and treasurer of the society. The thirty-first annual meeting will be held in St. Louis, in November, 1935, again in conjunction with the Southern Medical Association.

THE Perkin Medal of the Society of Chemical Industry will be presented to Dr. George O. Curme, Jr., of the Carbide and Carbon Chemicals Corporation, on January 11. Among the speakers at the meeting, at which five national chemical societies will be represented, will be Dr. E. R. Weidlein, director of the Mellon Institute, Pittsburgh; Professor Marston T. Bogert, of Columbia University, past-president of the Society of Chemical Industry, will make the presentation, and Dr. Curme will deliver an address entitled "Industry's Toolmaker," in which he will give an account of his work.

THE twelfth annual American Association prize of one thousand dollars has been awarded to Dr. Vern O. Knudsen, University of California at Los Angeles, for his paper, entitled "The Absorption of Sound in Gases." This paper was delivered at a joint session of the American Physical Society and the Acoustical Society of America, meeting under Section B (Physics) of the American Association.

ON the closing day of the annual congress of the British Institute of Radiology, Sir William Bragg was presented with the Mackenzie Davidson Medal following the delivery of the fifteenth Mackenzie Davidson Memorial Lecture in which he discussed the nature of organic molecules.

Nature reports that the gold medal for 1934 of the Royal Agricultural Society of England has been awarded to Sir Arnold Theiler, formerly director of veterinary research in South Africa, for his work in veterinary pathology, which over a period of more than thirty years "has been of tremendous benefit to mankind in the Union of South Africa and to the Empire as a whole."

THE Déjerine prize of the French Society of Neurology, Paris, has been awarded for 1933 to Dr. Laruelle, of Brussels.

The British Medical Journal states that at a meeting of the French Academy of Medicine on November 6, Dr. Siredey congratulated Dr. Guéniot, of the section of surgery, on his one hundred and second birthday.

DR. ALBERT VON SZENT-GYORGYI, of the University of Szeged, Hungary, will be during February visiting lecturer of physiology at Harvard University.

DR. FREDERICK G. NOVY, professor of bacteriology and dean of the Medical School of the University of Michigan, will retire from active service at the end of the present semester. Dr. Novy has been associated with the university for forty-eight years, becoming assistant in organic chemistry in 1886. He has been professor of bacteriology since 1902 and director of the Hygienic Laboratory since 1909.

DR. THOMAS J. LEBLANC has been promoted from associate professor to professor of preventive medicine in charge of a new department of preventive medicine at the University of Cincinnati College of Medicine.

DR. KENNETH S. RICE, formerly acting head of the department of biology of the University of Maine, has

joined the staff of the department of physiology, of the College of Medicine, University of Tennessee, Memphis.

HELEN F. TUCKER, formerly assistant professor of inorganic and analytical chemistry at Russell Sage College, has been appointed assistant professor of chemistry at Skidmore College, Saratoga Springs, N. Y.

DR. MURIEL ELAINE ADAIR has been elected to a second John Lucas Walker Scholarship at the University of Cambridge. This studentship, valued at £300 a year, was founded in 1807 under the will of the late John Lucas Walker, of Trinity College, for the furtherance of original research in pathology. It is open to persons of either sex, and the student need not necessarily be a member of the university. Mrs. Adair is the wife of G. S. Adair, fellow of King's College.

DR. ERWIN E. NELSON, associate professor of pharmacology at the University of Michigan, was recently appointed principal pharmacologist in charge of the Drug Division of the Food and Drug Administration of the U. S. Department of Agriculture. Dr. Nelson had been retained previously as an occasional consultant on specific questions and as an expert witness in court cases.

E. P. POLUSHKIN, formerly instructor in metallography at the School of Mines, Columbia University, has been appointed associate metallurgist, with particular reference to research and development, with Louis Pitkin, Incorporated, New York, N. Y.

N. K. CHANEY, assistant director of research of the National Carbon Company, Cleveland, Ohio, a member of the staff for eleven years, has resigned to accept a similar position with the United Gas Improvement Company, Philadelphia.

W. S. MANSFIELD, Emmanuel College, has been appointed director of the University Farm of the University of Cambridge.

T. H. C. TAYLOR, entomologist of the Coconut Committee, Fiji, has been appointed assistant entomologist to the Agricultural Department, Uganda.

THE Committee on Scientific Research of the American Medical Association, of which Dr. Ludvig Hektoen is chairman, has granted a sum of money to the Surgical Research Laboratory of the Stanford University School of Medicine for the prosecution of Dr. Frederick Fender's work on the "Effect of Prolonged Electrical Stimulation of Selected Components of the Nervous System in Animals." The committee has also renewed a grant to Dr. John Guttman, assistant professor of otology at the Columbia University Post-Graduate Medical School, for his work on the electric potential produced by sound in the auditory apparatus.

DR. MAURICE N. RICHTER, assistant professor of pathology at Columbia University, is visiting Puerto Rico, where he will give a series of clinico-pathological conferences before the faculty and hospital staff of the School of Tropical Medicine. He will also assist in the work of the department of pathology.

DR. L. H. BAEKELAND, honorary professor of chemical engineering, lectured recently at Columbia University on "Detriments and Stimulants in the Chemical Industry."

DR. WILLIAM E. GALLIE, professor of surgery, University of Toronto Faculty of Medicine, will deliver the 1935 Shattuck Lecture of the Massachusetts Medical Society.

SIR DANIEL HALL, chief scientific adviser to the British Ministry of Agriculture, has been appointed Rede lecturer for 1935. The lecture will be delivered on March 4.

MERVYN O'GORMAN read a paper entitled "Bringing Science into the Road Traffic Problem" before the British Science Guild at the Royal Society of Arts on December 19.

THE American Institute's Christmas Lectures on "The Frontiers of Science" were given in the auditorium of the American Museum of Natural History, New York, on December 26 and 27. Each lecture was attended by about fifteen hundred young people. The lectures were arranged by the institute in recognition of the work in science done by boys and girls in their after school hours. Dr. Harold C. Urey, of Columbia University, gave the first lecture on December 26 on "Heavy Water." He was followed on the same day by Dr. Robert Chambers, research professor of biology at the Washington Square College of New York University. His lecture was entitled "Glimpses into the Mechanics of Cell Life." Jeannette Piccard, pilot and co-explorer with her husband, Dr. Jean Piccard, on their recent trip into the stratosphere, was the first speaker on December 27. Mrs. Piccard explained the scientific significance of their flight in the study of cosmic rays. She was followed by Russell Owen, correspondent of *The New York Times* on the first Byrd Expedition to the South Pole. Mr. Owen spoke on "Exploring the Antarctic." Mr. Robert T. Pollock, trustee of the American Institute, and Dr. Roy Chapman Andrews, vice-director of the American Museum of Natural History in charge of exploration, introduced the speakers. Those who attended the lectures were members of the American Institute's Junior Science Clubs. In addition, honor

students in science were invited from high schools in the suburbs surrounding New York. These students were selected, in each case, by their high-school principal because of the excellence of their work in science. The lectures are patterned on the Christmas Week Lectures held for young people for over a century by the Royal Institution of London.

ACCORDING to *Nature,* the twenty-fifth annual exhibition of scientific instruments and apparatus arranged by the British Physical Society was held on January 1, 2 and 3 at the Imperial College of Science and Technology, London. The leading manufacturers of scientific instruments exhibited their latest products in the trade section. The Research and Experimental Section contained contributions from most of the important research laboratories in Great Britain, and there was a special subsection devoted to experiments of educational interest. In addition the work submitted for the craftsmanship competition by apprentices and learners was on view. Discourses delivered during the meeting were: January 1, Dr. B. Wheeler Robinson, "The Architecture of Molecules"; January 2, Dr. C. V. Drysdale, "The Problem of Ether Drift"; January 3, Dr. H. Spencer Jones, "Giant Telescopes."

THE post-doctorate fellowships in the biological sciences (zoology, botany, anthropology, psychology, agriculture and forestry), available through the National Research Council for the academic year 1935–1936, will be awarded by the Board of National Research Fellowships in the Biological Sciences at a meeting which is to be held the latter part of March. Applications should be filed with the office of the board by February 1. Appointments may be made prior to the conferring of the doctor's degree, to be effective upon the receipt of the degree within six months. Application blanks and statement of conditions will be furnished upon request by the secretary of the Board of National Research Fellowships in the Biological Sciences, National Research Council, Washington, D. C.

EIGHT more of the thirty-three institutions selected four years ago by Calvin Coolidge, Alfred E. Smith and Julius Rosenwald as the proper beneficiaries of the estate of Conrad Hubert, who died in 1928, soon will receive a total amount of $1,000,000. The accounting, covering a period from October 4, 1930, to October 1, 1934, shows that payments of $4,600,000 have been made as previously announced to fifteen institutions also chosen by the committee of three which disposed of the $6,000,000 left for that purpose by Mr. Hubert, who came to this country from Russia as a penniless boy and made a fortune with his invention of the flashlight. The contemplated payments follow: University of Chicago, $250,000; Henry Street Settlement, $100,000; American Foundation for the Blind, Inc., $100,000; Beth Israel Hospital Association, $200,000; Howard University, Washington, $200,000; William and Mary College, Catholic University of America and University of Virginia, $50,000 each.

THE late Dr. Roland B. Dixon, of Harvard University, created in his will trust funds of about $25,000 for the benefit of Harvard University. His books on American archeology and ethnology are left to the Harvard University Library and the Peabody Museum library and a number of his personal effects and other books are bequeathed to the president and fellows of Harvard College for use in the museum. $1,000 is bequeathed to the library of the town of Harvard. From the residue of the estate two trust funds are established at the university. One is to be known as the Roland B. Dixon Fund and the other as the Lewis S. Dixon Fund. The income of these funds is to be used for the purchase of books on anthropology and archeology and particularly of books concerning the American Indians.

AN endowment of $10,000 for an annual award in the interest of the progress of aviation has been provided by Dr. Sylvanus A. Reed, of New York. Fellows of the Institute of the Aeronautical Sciences will select the recipient of the award who will receive a cash prize of $250 and a certificate of merit. The award will be for "the greatest advance in the aeronautical sciences resulting from experimental or theoretical research, the beneficial effect of which on the development of practical aeronautics is apparent." The first award will be made at the annual meeting of the institute at Columbia University on January 30.

JOHN D. ROCKEFELLER, JR., has given to the Rockefeller Institute for Medical Research the block of land bounded by York and First Avenues, Sixty-seventh and Sixty-eighth Streets. Mr. Rockefeller is reported to have assembled the land over a long period originally, it is said, with the intention of using it for the Memorial Hospital, formerly the New York Cancer Hospital.

A COMMITTEE from the medical faculty of the University of Virginia has been appointed to work with architects in drawing detailed plans for the new wing of the University of Virginia Hospital which will be made possible by a recent Public Works Administration grant of $208,500. Dr. James Carroll Flippin, dean of medicine; Dr. Robert V. Funston, professor of orthopedic surgery; Dr. John H. Neff, professor of urology; Dr. Tiffany John Williams, professor of obstetrics and gynecology, and Dr. Carlisle S. Lentz, superintendent of the hospital, form a committee of

the faculty in charge of the construction of the new wing.

THROUGH the help of the Yellowstone Library and Museum Association, the Naturalist Department of Yellowstone National Park has made progress during the past year. The library which has now been catalogued contains 1,442 bound volumes, 1,862 pamphlets and bulletins, and a large number of magazines and periodicals. Gifts received during the year include original sketches made by Dr. W. H. Holmes and Mr. Henry Elliott, of the Hayden Surveys; an unpublished manuscript by Captain G. C. Doane detailing a trip through Yeulowstone and the Grand Tetons in 1876–1877; also a collection of fossils made by the early members of the Hayden and Hague surveys in Yellowstone Park, loaned by the U. S. National Museum to the Yellowstone Museums.

DISCUSSION

REPORT OF THE SCIENCE ADVISORY BOARD

EARLY in the week of December 9 the president released the report of the Science Advisory Board. About fifty preliminary copies of this report were released to the press. The bound copies will be ready for rather wide distribution to libraries, Congress, government officers, members of the National Academy of Sciences and others during the first week in January.

Quite unexpectedly a large section of the press featured practically the only aspect of the activities of the Science Advisory Board which has not been at least partially successful, and an aspect which was included in the report, merely as part of the historic record of the activities of the board. I therefore feel that a brief explanation may be of interest to supplement the official news release from Science Service which has already appeared in SCIENCE.

The publicity referred to centered around the proposal of a "Recovery Program of Science Progress" which had been presented to the Public Works Administrator on September 15, 1933, for his consideration as a means for providing useful employment to the large numbers of scientists who at that time were being dropped by government bureaus, industrial research laboratories and universities. It was definitely a proposal for emergency employment, designed to enable these scientists to find work of a type in which they could make valuable contributions to problems of social value.

It was proposed to expend a total fund of $16,000,000 on a tapering-off basis over a period of six years, on advice of a committee of scientists to be set up under the National Academy of Sciences and the National Research Council. No program of work was submitted since it was felt that the development of such a program should be one of the functions of the proposed advisory committee. There were, however, submitted a dozen or so examples of scientific or engineering problems of unquestioned social value and promise of successful solution, which were intended merely to illustrate the kinds of things which needed to be done and which might be submitted to the advisory committee and the Public Works Administrator if the plan were authorized.

This proposal was sponsored by some thirty-five executive officers of the national engineering and scientific societies, including the Science Advisory Board. It was submitted to the Public Works Administrator in person, by Dr. Alfred D. Flinn, director of the Engineering Foundation, and myself. After a considerable discussion, Mr. Ickes said that he was 99 per cent. convinced that something of the sort should be done, but that there was unfortunately no provision under the law whereby public works funds could be expended for research but only for construction.

The matter was dropped at that point and was included in the report of the Science Advisory Board only as an historic document because the board assisted in the formulation of the proposal.

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BEHAVIOR PATTERN AND BEHAVIOR MORPHOLOGY

THE word *Morphologie* when first coined by Goethe was used in relation to physical structure. The term still carries physical connotations. But the concepts of morphology can be extended to the phenomena of behavior. Morphology is the science of form. Form is the shape of anything, as distinguished from the substance of that thing. Behavior has shape, temporal and spatial. It is never amorphous. It has pattern in the momentary phase; it has pattern in the series of moments that make an episode; it has pattern when regarded in the full perspective of the life cycle.

The form characteristics of behavior pattern can be investigated in their own scientific right. A morphological approach concerns itself chiefly with problems of form—the description and measurement of specific forms; the systematic study of the topographical relations and the correlation of these forms, their ontogenetic progression and involution, their comparative features among individuals and among species. Any psychological theory which is so ab-

stractly dynamic that it overlooks or slights basic problems of form-production is at least incomplete. The individual is a *morphon* as well as a *bion!*

In the field of developmental psychology it is peculiarly important that the total behavior complex should be envisaged and explored from the standpoint of morpho-genesis. This complex lacks corporeal tangibility; but it does not lack form characteristics. The action systems of embryo, fetus and infant undergo progressive changes of pattern which are so consistent that we may be certain that these changes are governed by mechanisms of form regulation comparable to those which are being established by the science of embryology. Fundamentally, no doubt, the growth of tissues, of organs and of behavior is patterned by identical laws of developmental morphology. It may even prove that certain principles in the physiology of development such as polarity, symmetry, organization center and induction influences will find a modified status in the concepts of psycho-genesis.

The term *behavior pattern* is confessedly protean, but it can not be misleading if the aspect of form consistently receives major emphasis. A pattern of behavior is a configured response which can be concretely described in terms of a given situation. A *behavior item* is a feature or a component of a pattern, ascertainable by analysis. Neither pattern nor item has status as a circumscribed entity. A pattern always has context, and this context if analyzed can in turn be reduced to constituent patterns. But since contexts also have contexts, it follows perhaps that the only pattern which has complete integral status is the organismic pattern which is the individual himself.

Behavior patterns therefore range from minute manifestations, like the wink of an eyelid and the wag of a finger, to the complicated sequences of problem solving and of personality response. A durable task of genetic psychology is to find among the multitudinous patterns of infancy, similarities, modalities and growth-trends which are so fundamental that they give token of the adult, who is to be. This, I would hold, is first of all a morphological or a morphographic task.

A complete description of any behavior pattern would have to take into account the total stimulus pattern as interpreted by Klüver. But coordinate and final consideration must always be given to the form-producing and the form-limiting factors which are resident in the growing organism. Environmental factors inflect, but they do not generate the progressions of development. The maturational matrix is the morphogenetic substratum in which the behavior mechanisms are organized. This matrix is not a diffuse, homogeneous colloidal essence of some kind, but a structured reality which must be scientifically considered in morphological terms.

Now, with this prelude, we may examine a convenient and very suggestive series of behavior patterns, namely those that pertain to the infant's index finger. Let us see whether this finger points to any conclusions.

As early as the eighteenth prenatal week the fetal index finger is capable of spontaneous, undirected movement. But the index finger of the newborn infant remains relatively inactive and is crooked in a clenched fist night and day. In the Yale normative survey the hand posturing of scores of infants was observed while they lay basking in a supine position. The observations, confirmed by cinema records, show that the hands remained predominantly closed in over half of the infants at 4, 6, 8 and 12 weeks of age. But at 20 weeks the hand is predominantly open and the index finger, along with its associates, asserts itself in an interesting pattern of activity, mutual fingering. In this fingering the digits begin to define their separate identities, both as agents and as recipients of impressions. In prehension and manipulation, however, the digits function conjointly, the ulnar digits, as shown by Halverson, taking the lead in functional differentiation.

This retardation in the behavior patterning of the two radial digits, thumb and index, is unquestionably a morphological phenomenon. It is correlated with the very topographic anatomy of these ultimately opposable digits; and is bound up by ramification with far-reaching postural reorientations which involve the wrist, the forearm, the upper arm, the shoulder, eyes and head. The progressive predomination and specialization of the index finger is essentially a process of postural moulding. The inherent morphogenetic character of this process is strikingly displayed in the development of the prehensory reactions to a 7 mm pellet placed before the seated infant at advancing age levels:

At 24 weeks the infant contacts the pellet with pronate hand, in a pawlike manner, with no finger adjustments.

At 28 weeks he flexes his fingers upon the pellet.

At 32 weeks he grasps it by a simultaneous raking flexion.

At 36 weeks he grasps it between thumb and index.

At 40 weeks he approaches and contacts the pellet with extended index. He pokes and pries with his index.

This poking projection of the index is a pattern characteristic so well defined that at 40 weeks it is almost as plain as the nose on his face. It is a new form of behavior, and like the profile of his nose, it is an intrinsic morphogenetic product.

The developmental basis of this poking proclivity

came to very pretty expression in our study of Twins T and C by the method of co-twin control (Gesell and Thompson). Detailed comparative observations of the behavior characteristics of these twins were made. A thoroughgoing identity was established prior to the experimental investigation. On one examination both twins made a raking approach on the pellet, with simultaneous flexion of the digits. Two weeks later under the same conditions each twin approached each pellet with projected index and each twin placed the tip of the index on the pellet. These remarkably similar changes in prehensory pattern occurred contemporaneously, without specific training or imitation.

The preeminence of the index (and thumb) can scarcely be set down as an act of skill acquired primarily by learning. The learning process has no architectonic mechanism which can account for such a topographic alteration of behavior pattern. Training and experience perfect and inflect, but always in specific and immediate confines. They do not engender the basic reconfigurations of behavior. Else, why does not our infant become an expert raker of pellets by gross manual approach, instead of a temporarily ineffectual plucker by refined, digital approach?

It is of crucial significance that the poking propensity asserts itself not only in the presence of small objects like the pellet. The poking is not the consequence of a unique stimulus pattern. The infant pokes in the presence of the cube, the bottle and the bell, as well as the pellet. He may poke in the presence of the extensive, flat-table top. The infant you saw on the screen[1] displayed specialized mobility and extension of the index finger, even when at 40 weeks he stood, eyes front, in his pen outdoors, and raised his free hand toward the circumambient sky. For a brief interval the index pointed heavenward. This behavior denotes the urgency and form-producing character of the internal stimuli which prompt him to poke and pry so inveterately at about 40 weeks of age. The index finger then becomes in fact the *fore* finger.

This poking, however, does not become stereotyped. It never is stereotyped in the normal infant. It begins somewhat sporadically and manifests itself sketchily. Early poking tends to be vague and fugitive; it may involve the thumb and medius; but steadily it defines. It becomes more prolonged; it becomes recurrent; it becomes more penetrating. Interestingly enough for a period the infant merely pokes near or at a hole large enough to admit his index (for example, the half-inch hole in the vertical side of the performance box); only at a later age does he thrust his finger well into the hole. He passes through a transitional period in which both digitally and probably perceptively he fails to penetrate into the third dimensional interior of things. But in due time he probes. His penetration becomes increasingly exploratory and exploitive. In the cinema infant this probing was associated with a mechanical kind of inquisitiveness which has been displayed in numerous life situations and already strongly indicates some form of mechanical aptitude.

New patterns differentiate with maturity, but they never completely individuate; rather, they articulate by ingrowth with concurrent patterns. While they are thus combining, yet newer patterns are differentiating and these in turn will be assimilated to the consolidating total action system. That total action system is an architectured entity, which can be adequately described only in morphological terms. It is the behavioral embodiment of the individual and his constitutional characteristics. Through it the individual as well as the species maintains identity.

The poking propensity and the poking pattern therefore constitute a well-defined example of individuation, a selective specialization of a minor member to subserve the developmental trends or needs of the organism. But that individuation is never complete or segregated, it is always partial and by extensive ramification it remains accessory to a fundamental unity of response.

In the progressive individuations and elaborations which are so palpably, almost naively, exhibited in the behavior patterns of the human fore finger, we have, I believe, a true image of the developmental mechanics of the higher mental processes. Now I do not wish to hang the whole world (and all its psychology) on the infant's extended index, but I would suggest that even in the intellectual spheres of adult invention we are dealing in essence with comparable morphogenetic phenomena. Our mechanistic assumption is that attention in infant and in man is primarily a function of pattern morphology. Acts of attention are dynamic or kinetic manifestations of patterned structure. They have a morphological status. All behavior patterns are therefore subject to morphological investigation.

If this approach is first of all descriptive, well and good. There is no royal road, even in psychology, to an understanding of the structuralization of human behavior. There has been no royal road to the science of human anatomy. We must be prepared to study the phenomena of human behavior with the same minute interest in structured form which the

[1] Prior to the paper, a talking film was shown: "The Growth of Infant Behavior: Later Stages." Yale Films of Child Development (Sound film No. 3, 1934). Erpi Picture Consultants, Inc., New York. See also Gesell, A. *et al.*, "An Atlas of Infant Behavior," Vol. I, pp. 402 *ff*. Yale University Press, New Haven, 1934.

disciplines of embryology and anatomy demand. The way is long and tedious, but the scientific footing is solid.

ARNOLD GESELL,
Director

THE YALE CLINIC OF
CHILD DEVELOPMENT

THE ORIGIN OF NATURAL OIL

THE writer of this article is compelled to adhere to his view expressed in SCIENCE of September 7, and questioned by Professor J. M. Macfarlane in the issue for November 23. The reasons are to be found in chemical and geochemical considerations. The specialist in the field of bituminous coal, natural asphalt and oil is struck with the relation of these substances. They consist of aliphatic, semi-aromatic and aromatic compounds. The presence of bituminous coal and oil in the same localities, but in different strata, for instance, near Pittsburgh, forces one to the point of view that both substances were formed from the same original material. If this point of view *and* the fish theory are correct, the origin of bituminous coal and oil would have to be traced back to dead fish. Probably few adherents will be found for such a theory.

The chemical world to-day rejects almost entirely the fish theory. Investigations by P. D. Trask and C. C. Wu[1] have shown that on distillation of samples of sea and lake water muds, which probably contain the remainder of dead fish, oil-like substances can scarcely be obtained. The quantity of oil received therefrom was exceedingly small.

Investigations have shown that under geochemical conditions the teeth and bones of fish remain almost intact. In rocks containing oil fewer inorganic relics of fish are found than undamaged parts of cellulose and wood.

The so-called catastrophe theory has been invented to save the fish theory. The entrance of fresh water into sea water or sea water into fresh water is supposed to have led to the death of enormous quantities of fish. Professor Macfarlane believes volcanic and seismic causes are responsible for this. It is difficult to explain from such a point of view the presence of oil in different strata above each other. Such would mean that catastrophes occurred at the same place at several different times.

Carbohydrates are produced by nature in the greatest degree; probably even more so in earlier periods. The quantity of fish compared to this is small. The presence of enormous quantities of oil in the interior of the earth is therefore contrary to the fish theory. It is more than probable that the savings buried by nature in the form of coal and oil in the earth originate principally in the enormous quantities of carbohydrates and carbohydrate-humic acids transformed therefrom (not lignin-humic acids) and very little, if any at all from fish.

The question of the origin of oil and bituminous coal may be clarified only by experiments and observation of thermo-dynamic, geological and geochemical conditions. The carrying out of experiments should take place under geochemical conditions. In this respect, the writer of this article has to criticize the otherwise valuable experiments carried out by Warren and Storer.[2] Warren and Storer decomposed at "red hot heat" the lime soap which was produced on saponification of fish oil with strong excess of lime. All those who have been engaged with research work on the origin of oil know that neither the action of strong hydrate of lime nor such high temperatures were possible during the formation of oil. At the low temperatures which must be considered here, the lime soap would have to be stable. In any case, it would not lead to the formation of aromatics, such as has been observed in crude oil. From a thermodynamic view-point, the transformation of aliphatic hydrocarbons formed from aliphatic acids into ring hydrocarbons is not possible at lower temperatures. The temperatures required for such transformation are above the temperature for the formation of crude oil, which certainly has not gone beyond 300° C. One can find derivatives of chlorophyll in all crude oils and asphalts. These substances are completely destroyed at temperatures above 300°.

For the formation of aromatic compounds, therefore, other reactions must be responsible. Carbohydrates may be transformed at comparatively low temperatures into semi-aromatics and aromatics (phenols and phenolcarboxylic acids). By such reactions the presence of aromatics and naphthenes in crude oil is not difficult to explain.

On the basis of his own experiments and because of thermodynamic, geological and geochemical facts, which are contrary to the fish theory, the writer of this article can not adhere to the truth of the aphorism that "fish is the source of petroleum." His experimental work and that of his collaborators in this regard will be published elsewhere.

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LUNAR RINGS

ON the evening of November 22, 1934, San Franciscans were treated to a display of spectral rings about the moon. It was first noticed by us from the steps of the Academy of Sciences at 10 P. M.,

[1] *Bull. Am. Ass. Petrol. Geol.*, No. 11, 1928, and 1451, 1930.

[2] "Amer. Acad. Arts and Sc. Memoirs," S2, 9, page 177, 1867.

but residents had been observing it for an hour or more. The moon was full and high overhead. Fleecy streaks of cloud, commonly termed "high fog," much too thin to obscure the disk, drifted slowly across; these seemed to be the cause of the unusual phenomenon. When we first saw it there was an inner circle, about six moon-diameters, bright, opalescent white, followed by the spectral rings from red to violet. The total diameter of the violet ring was about 12 moon diameters. Each color was sharply separated from its neighbors and the whole formed a magnificent and brilliant exhibit of the spectrum. The intensity and purity of the colors seemed to be much more pronounced than is usually seen in solar rainbows.

Points of visibility were somewhat localized. On Geary Street, five blocks away, the rings were gone and the moon was surrounded only by the opalescent disk, fading gradually outwardly. A few minutes later, at the academy, the spectral band was even more brilliant and sharply defined than when first observed, due apparently to its having shrunk to about half its former diameter. Six blocks away a few minutes later it had disappeared.

The variation in size was doubtless the result of the difference in elevation of the cloud. A slight tendency to become oval in shape was noticed occasionally, and this was probably also caused by variable thickness and elevation of the refractive stratum.

G. D. HANNA
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SCIENTIFIC BOOKS

THE STORY OF A MIND

Franklin Paine Mall, The Story of a Mind. By FLORENCE RENA SABIN, M.D., Member of the Rockefeller Institute for Medical Research. The Johns Hopkins Press, pp. i–xiii, 1–342. $2.75.

HERE is the fascinating story of the life and work of one of the outstanding figures in the promotion of research in anatomy and embryology and in the reorganization of medical education in the United States. From a farm in Iowa and from a village school, Franklin Paine Mall, of German blood from both parents, went to the Medical Department of the University of Michigan in 1880 and in 1883, at the age of 26, was graduated with the degree of M.D. Stimulated by an inner drive for more knowledge he went to Germany without any very definite plan; but, with the thought that he wanted to know more about ophthalmology, he spent the academic year of 1883–84 at Heidelberg University and at the end of that year, realizing that his interests were chiefly in anatomy and embryology, he went to Leipzig and sought and obtained the privilege of working under the foremost authority in the world on those subjects, Wilhelm His. Here he learned the latest methods of research in embryology and, still more important, the value of exact methods in scientific research. A research topic was assigned him and he was encouraged to work independently, and the independence and thoroughness of his work were demonstrated by the fact that in this, his first research, he reached conclusions at variance with those of his revered professor, who subsequently acknowledged his own mistake and for the remainder of his life remained a devoted friend of Mall.

A third year in Germany he spent in the laboratory of the distinguished physiologist, Carl Ludwig, in Leipzig, and it is no exaggeration to say that Ludwig then and ever after treated him as a beloved son. He not only suggested an important problem of research and gave constant encouragement and frequent advice, but when the results of this and of later researches were submitted to him for publication, he edited them and even had the illustrations redrawn—and all with a delicacy of suggestion and a pride in the work of his young friend which was certainly most unusual and which indicated that he recognized in Mall a person of extraordinary ability and promise. When Mall expressed his great obligations and asked how he could ever repay them, he was told merely, "Pass it on!"

This ideal association with Ludwig was probably the most potent factor in shaping Mall's career, and in after years his aid and encouragement to those who did research work in his laboratory, and the love and admiration which they had for him, are evidences that he followed Ludwig's admonition to "pass it on."

On his return to the United States, Mall sought and obtained a fellowship at the Johns Hopkins University under Dr. Welch, whom he had met in Ludwig's laboratory and who ever after remained his great friend and admirer. This fellowship in pathology he held from 1886 to 1889. From 1889 to 1892 he was adjunct professor of anatomy in Clark University, and on the organization of the new University of Chicago he joined or rather led the migration from Clark to Chicago, where for a single year 1892–93, he was professor of anatomy in the Division of the Biological Sciences. He then yielded to the persuasions of Dr. Welch to accept the chair of anatomy in the newly organized Department of Medicine at the Johns Hopkins University, and this position he held until his death in 1917.

This bare outline of Dr. Mall's university connec-

tions gives no hint of the importance and thoroughness of his research work, which was published in more than one hundred monographs and contributions, nor of his great service in training dozens of the leading anatomists and embryologists of this country, nor of the leading part he took in the establishment of research journals, nor of his unceasing labors for the reorganization of medical education in this country. All this and much more is told with a wealth of detail and a great measure of admiration and affection by one of his former students and associates, Dr. Florence Sabin, in the book under review. This volume is not merely "the story of a mind," as the sub-title phrases it, but it is also the story of an era in medical science and education—the story of the transition of many medical schools in this country from the status of trade schools, conducted in many instances for the profit of proprietors and therefore with little or no laboratory facilities and with no regard to research, to the full stature of university departments for graduate study. In this transitional era the Johns Hopkins University, established in 1876, and its Medical School, fully organized in 1893, took a leading part, and probably no member of its staff was more influential in bringing about this transformation than Dr. Mall. His own standing as an investigator, his high ideals for medical education and especially his far-sighted planning accomplished more in the reform of medical education in America than is generally recognized, for he worked quietly and often through others who received the credit for what he had planned and started.

His method of teaching was almost completely different from that usually practised. Partly because he was not himself a public lecturer and partly because of his own experience in the laboratories of His and Ludwig, he taught by the inductive laboratory method, assigning problems and materials and leaving students to do the work. This was the method of His and Ludwig, of von Baer and Louis Agassiz, and in the form of "autonomous courses" it has of late begun to displace didactic lectures in many colleges and universities.

The important part which Mall took in the establishment of the *American Journal of Anatomy* and the *Anatomical Record,* as well as his last great work in bringing about the establishment in Baltimore of the Department of Embryology of the Carnegie Institution of Washington is described in this book. Also his leadership in the campaign for full-time clinical professors in medical schools is outlined, and here, for the first and only time in this book, Dr. Sabin indicates "a limitation in Mall's vision—that he underestimated the amount of technical skill actually in possession of the medical profession and the time necessary to acquire it." And this suggests that in general the book is written from the standpoint of a devoted follower of Mall rather than of an impartial judge. In particular the contrast in medical science and education before and after Mall is over-emphasized, as for example when it is said that his "program, contrasted with the ones which preceded it, is like a breath of fresh air and reminds one of the awakening of Rip van Winkle in a new era" (p. 225). And when it is stated that "to Newall (sic) Martin belongs the credit for starting modern physiological research in this country" (p. 27) one should recall some of the eminent physiologists who were Martin's predecessors or contemporaries. Other cases of such over-emphasis are evident throughout the book. There can be no question as to the great stimulus given to medical science and education by the Johns Hopkins University and by Dr. Mall, but there were other men and institutions in the forefront of this advance; on the whole, however, this is a faithful account of the great part taken by Mall in this advance.

It may seem ungracious to call attention to a number of errors, most of them trivial, but in the interest of accuracy the following errata should be noted: on page 6 the date 1885 should be 1855; everywhere (pp. 13, 14, 15, 16, 197) the name of the founder of the first medical school in America is given as "Shippan" instead of Shippen. Among those members of the faculty of Clark University who migrated to Chicago in 1892 Bolza is erroneously assigned to chemistry instead of mathematics while Nef, Watase and Wheeler are not mentioned and Lillie appears as "Lilly" (p. 88). On page 190 Miall should be substituted for "Mall" and on page 214 Linton for "Linten." Among the journals in which Joseph Leidy is said to have published his researches is listed the *Proceedings of the National Academy of Sciences,* which was not established until eighteen years after Leidy's death; evidently the *Proceedings of the Academy of National Sciences of Philadelphia* is intended. The statement on page 236 that "scientific journals were new to this country when the *Anatomical Journal* was started" is either a "slam" at the several reputable journals that had long been in the field or it is an oversight.

No doubt these and other minor errors are "slips" which will be corrected in any future edition. On the whole, this book is an inspiring account of the life, scientific work and educational activities of an extraordinarily able and forceful leader whose significant work remains after him, although his quiet and retiring personality has caused him to remain relatively unknown.

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RECENT ZOOLOGICAL TEXT-BOOKS

DURING the latter part of 1933 and the whole of the year 1934 six new works have come to the reviewer's desk. Brief summaries of these follow.

The zoological text-books which have come from the presses of various publishers in the United States during the past few years are of three types, with various degrees of intergradation: (1) There are original works which have been carefully prepared by thoughtful, competent and alert professional men of high standing (Curtis and Guthrie; Shull, Larue and Ruthven; Guyer; Woodruff; etc.). These to some degree represent the labors of those who love science and students, and who have ideas and ideals about how things should be done. They often present new points of view and contain original illustrations. The statements which students are to read are carefully considered, critical and "scientific." One may not approve of an author's plan of treatment or of some of the opinions expressed, but such works must be treated with respect. Some of these books raise standards of teaching and thinking, as well as give information. (2) There is another class of works which are opportunistic compilations by those who write books to sell. They seldom contain original figures or ideas. They are usually encyclopedic rehashes which will be useful to a great body of not-too-well-trained, time-serving teachers. They sell because they are mediocre, conservative or perhaps even a little backward in their outlook. They perpetuate old dogmas and poor figures, which every zoologist knows only too well. Students get no ideas from such books. (3) There is unfortunately another group of books which perhaps never should have been written or published. They are the works of poor writers and perhaps even ignorant, incompetent, narrow-minded or bigoted zoologists. Students who try to use these books are often confused and worried. The writers of such books continually attempt to intrigue their readers to agree with them by the frequent use of "we" and "our." They often refer loosely and uncritically to the body, the animal, forms, higher, lower, etc. They are unprogressive because they get their own information from other text-books, and not from new, inspiring, original sources.

A glossary seems to be a rock on which many authors founder. Many attempts to define terms appear, in the hands of zoological text-book writers, to result in statements which give students a very limited or distorted view. Perhaps it may be better for writers to omit glossaries and depend instead on a good dictionary which is made readily accessible to students in a laboratory or library.

The appearance of a text-book of general science for college students raises the old question of the content of beginning courses. Shall such courses be broadly informative or give technical training in methods of scientific thought and procedure? Shall students be taught the interesting and inspiring generalizations which have resulted from zoological or botanical study without knowing about animals or plants as such? Shall the backbone of a course be general principles, types, natural history, systematics or what? Shall teachers give students what they would most like to know and what may be most useful as equipmnet for an educated man in modern society, or shall teachers train students to be real scientists in a small way? The University of Chicago now requires all students to take four broad informational courses during the first two years. This is avowedly an attempt to give students a broad point of view rather than a technical limited one. Schiller[1] says:

> The interest of the professor is to become unassailable, and so more authoritative. He achieves this by becoming more technical. For the more technical he gets, the fewer can comprehend him; the fewer are competent to criticize him, the more of an oracle he becomes. If therefore he wishes for an easy life of undisturbed academic leisure, the more he will indulge his natural tendency to become more technical as his knowledge grows, the more he will turn away from those aspects of his subject which have any practical or human interest. He will wrap himself in technical jargon and become as nearly as possible unintelligible.

The teacher is always in a dilemma. Shall he try to give students a real view of the inwardness of the subject he has spent his life in mastering or shall he artfully and tactfully select the essential things from his field of learning which will enable his students to live better lives? There is only one Huxley in each generation. A small man who attempts to write a popular text-book which is not technical and critical may do nothing but present superficial, sentimental slush. It is better to be technical than silly. The writing of a well-balanced, thoroughly scientific and interesting book which is suited to the needs of students requires a rare degree of knowledge and judgment.

Probably the scientific text-books of the future will be less technical. The increasing costs of laboratory instruction on a large scale and the continual failure of technically informed college graduates to take up the ordinary duties of life without retraining themselves make educational administrators strong advocates of general informational courses. The professional scientist hates superficiality and loose thinking, but loves accuracy and truth. He therefore fears "general" courses. Yet common sense indicates

[1] F. C. S. Schiller, "Tantalus." N. Y. vi + 66. 1924.

that he must be less technical. If scientist-teachers will seriously consider this problem they can probably show a little more human interest without sacrificing scientific spirit.

An Introductory Course in Science for Colleges. By FRANK COVERT JEAN, EZRA CLARENCE HARRAH, FRED LOUIS HERRMAN and SAMUEL RALPH POWERS. *I. Man and the Nature of his Physical Universe.* x + 524 pp. *II. Man and the Nature of his Biological World.* Ginn and Company, New York. 1934. $2.20, $2.40. This two-volume work is intended for a broad, cultural course in science. The first volume deals with astronomy; matter and energy; mechanics, electricity, aeronautics and inventions; meteorology and geology. The second begins with a discussion of protoplasm and then considers the adaptations of plants and animals for life, metabolism, evolution, ecology, heredity, man's place in nature, nutrition, hormones, public health, archeology, anthropology and sociology. Each volume has a rather limited glossary at the end. In general the work is well written, interesting and at times inspiring. Good taste is used in the selection of material which students will understand. Though the treatment is often more or less popular, as it must be because such a wide range is covered, it is thoroughly scientific.

Laboratory Outlines for Animal Biology. By MICHAEL F. GUYER and HALCYON W. HELLBAUM. xiv + 240 pp. Harper and Brothers, New York. 1933. $1.50. The first part of this manual deals with frogs in detail and the second with other representative types of animals. The work is presented as 72 exercises for two-hour laboratory periods. Though the treatment is largely descriptive, suggestive questions are often asked, and a list of topics for discussion is found at the end of each exercise. There are also some comparative tables to be filled in and drawings to be labeled. Blank pages for drawings and notes are interpolated.

General Zoology. By FREDERICK H. KRECKER. xi + 634 pp. Henry Holt and Company, New York. 1934. $3.50. This book attempts to present zoology for those who desire a liberal education, rather than training for specialization. It begins with a section called "A Typical Animal," which "deals with physiological and morphological principles applicable to animals in general" and introduces "the cell and the ascending order of units into which it is organized." This is followed by a systematic survey of the chief phyla of animals. In each chapter a group is first described in a semi-popular manner; then follows a somewhat more technical discussion of morphological features; and finally there is a systematic summary in which classes and orders are briefly characterized. A third section considers animals in relation to environment. A final section, entitled "The Origin of Animals," deals largely with evolution and heredity. The book has been written by an experienced teacher who has used good judgment in presenting what students may read with interest and assimilate. It is unfortunate that there are at times careless errors and uncritical or misleading statements. For example, probably most zoologists do not believe that "since a specialized animal is thought of as being higher in the scale than a generalized form the terms higher or advanced and lower or primitive are used as synonyms for specialized and generalized respectively" (p. 159). In 1688 Francesco Redi said, "Besides, 'low' and 'high' are unknown terms to Nature, invented to suit the beliefs of this or that sect, according to the needs of the case." Such illustrations as Figures 333 and 334 appear to be poorly conceived and executed. In the first a katydid is properly designated; in the second another katydid is called a grasshopper.

Elements of Modern Biology. By CHARLES ROBERT PLUNKETT. Henry Holt and Company, New York. viii + 540 pp. $3.00. This is a book by a teacher for teachers. It is an abridgment and modification of "Outlines of Modern Biology" by the same author. The work is divided into five parts: (1) Protoplasm, seven chapters; (2) Nutrition, five chapters; (3) Response, five chapters; (4) Reproduction, four chapters; and (5) Evolution, three chapters. The treatment is from the point of view of general biology. Plants and animals are often considered together as illustrative material, but they are usually more or less ignored as such in order to present the physical and chemical basis for the phenomena of life. There is much of chemistry and physics and little or no natural history. Some of the statements are misleading, peculiarly limited or uncritical: *e.g.,* the discussion of parasitism (p. 110) and tropisms (p. 267); and in the glossary the definitions of such words as aberration, absorption, activation, adhesion, alternation of generations, analogous organs, etc. (p. 513). The work is perhaps a little heavy for students who are beginning the study of biology, but gives a thorough and thoughtful survey of the principles of biology.

Principles of Animal Biology. By A. FRANKLIN SHULL, GEORGE R. LARUE and ALEXANDER G. RUTHVEN. xiv + 400 pp. 4th edition. McGraw-Hill Book Company, New York. 1934. $3.50. This is a revision of a well-known and successful text-book. It considers the principles of zoology rather than types

or taxonomy. Though it is perhaps somewhat difficult for college freshmen at times, it impresses one as a well-written work by thoughtful, careful and competent zoologists. A new feature of this edition is a chapter on elementary chemistry and its biological applications. In twenty-one chapters the following topics are considered: biology, cells, protoplasm, chemistry, metazoans, mechanical support and movement, materials and energy, internal transport, disposal of wastes, unity and control, reproduction, breeding habits, development, genetics, classification, ecology, geographic distribution, fossils and evolution.

Animal Biology. By ROBERT H. WOLCOTT. xvii + 615 pp. McGraw-Hill Book Company, New York. 1933. $3.50. This book advocates the following principles: "(1) Life has a chemicophysical basis; (2) life phenomena are the outgrowth of organization; (3) the central fact in life is metabolism; (4) animals may be arranged in a progressive series with reference to organization; (5) the most complex animals are most effective and also the most efficient from a metabolic standpoint; (6) man, as the highest of animals, can learn by the study of animal life the principles of the most effective living; (7) he can also understand more fully his place in nature and more justly judge the actions of his fellows; this in turn may contribute to his intellectual and spiritual development; (8) every problem concerned with living is essentially a biological problem and capable of analysis and solution by the application of biological principles." The text is intended for the use of college students. Its writer was a teacher of long experience who has thoughtfully presented the general facts and principles of biology. The book contains fifty-five chapters grouped into five parts: (1) Fundamental Principles, (2) Protozoa, (3) Metazoa in General, (4) Metazoan Phyla and (5) General Considerations. It is well illustrated, a few of the figures being original. At the end is an excellent glossary, which not only defines scientific terms but also gives brief statements concerning authors mentioned in the text.

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

A TIMING DEVICE FOR TAKING MOTION PICTURES[1]

THE study of any morphological state attains its full value only when a record is taken of the stages which precede and which follow it. An apparatus was built to operate a motion picture camera automatically so that single exposures are taken in adjustable intervals from one second to ten minutes. When a film so exposed is projected with the normal speed of 16 frames per second the recorded process will be accelerated in a corresponding ratio.

In the recent literature several automatic devices were described, most of which are too elaborate, filling the space of a laboratory room, and being correspondingly expensive, while others show in their construction signs of amateurish work. Therefore, it became necessary to design a simple apparatus which is within the financial scope of any laboratory and yet is constructed precisely and sturdily to withstand long wear. This apparatus was built to operate the camera in exactly equal intervals, adjustable to any interval required, over long periods of time, and synchronously to put into action a source of light for each individual exposure; for it is obvious that the living object would suffer unnecessarily from the powerful light if it were not excluded during the long intervals between two exposures.

[1] The construction of this apparatus was made possible by a grant from the Committee on Scientific Research, American Medical Association, to whom the senior author expresses his obligations.

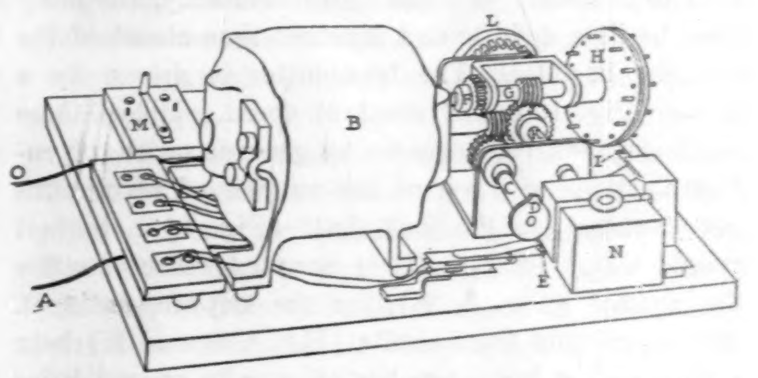

FIG. 1. The timing apparatus; *A*, power line; *B*, synchronous motor; *C*, first shaft; *D*, cam, operating *E*, the contact for the tripping magnet; *F*, worm and gear, connecting first shaft with second shaft (worm mounted on first shaft not represented in drawing); *G*, second shaft with peg disc *H*, (for intervals 1–20 seconds), operating contact *I*; *J*, worm and gear connecting second shaft with third shaft *K*; *L*, peg disk for intervals from 20–600 seconds; *M*, switch, short circuiting preparatory contact when operating in intervals below 20 seconds; *N*, condensors; *O*, three wire cable to plug board.

The equipment consists of a motor-driven impulse transmitter (timing apparatus), shown in Fig. 1, and B, B[1], in Fig. 2, and a tripping magnet (G, in Fig. 2) which by means of an adaptor ring is mounted on the motion picture camera. The timing apparatus transmits in regular intervals two current impulses. One operates the tripping magnet which—if energized—presses the release button of the camera for *one* picture. The other impulse lights the lamp (Fig. 2, K) for illuminating the object during the exposure.

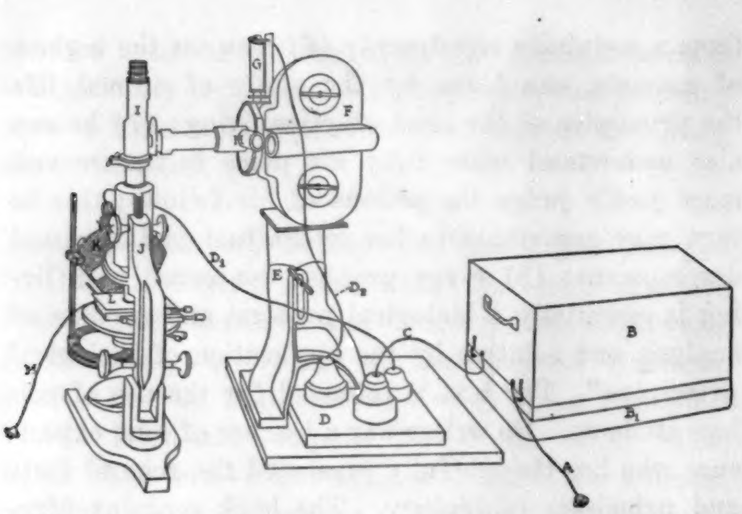

FIG. 2. General arrangement of the apparatus. *A*, power line; *B*, transmitter or timing apparatus; B_1, rubber mat; *C*, connecting line to the plug board; *D*, plug board; D_1, cable to microscope illuminator; D_2, cable to tripping magnet; *E*, base of the camera support; *F*, motion picture camera; *G*, tripping magnet; *H*, lateral, prismatic view finder (Goerz); *I*, "microphot" (Zeiss), bending the light by 90° from the vertical direction of the microscope horizontally into the camera; *J*, microscope; *K*, microscope illuminator; *L*, heating chamber; *M*, cord for heat chamber.

Since the incandescent lamp requires some time (from 1/20 to 1/5 sec.) to come up to brilliancy, the lamp must be lit a definite and constant time ahead of the tripping impulse. The transmitter is driven by a motor (Fig. 1, B) of constant speed. It has three shafts connected in sequence by gears in order to produce a stepping down of the number of revolutions per minute. On the first shaft (Fig. 1, C, highest speed) a cam (Fig. 1, D) is mounted which operates the contact (Fig. 1, E) for the tripping magnet. The second and third shafts (Fig. 1, G and K) bear a disk with a large number of equally spaced holes (Fig. 1, H and L). In these holes pegs are inserted which operate the contact in the lamp circuit. These pegs can be displaced by hand so that the contact can not be pressed when the disk is in rotation. Thus, the intervals between the impulses can be varied from 1 to 20 seconds (*i.e.*, 1, 2, 4, 5, 10, 20 seconds) depending on the number of pegs which press the contact during one revolution (Fig. 1, H). The length of one impulse is adjusted permanently in the machine (to approx. 0.6 sec.) by the location of the point of contact. For intervals longer than 20 seconds the second disk and contact (Fig. 1, L)—called the preparatory contact—is provided. This contact is in series with the lamp contact. While taking pictures in intervals shorter than 20 seconds, the preparatory contact is short-circuited by a switch (Fig. 1, M). If this switch is opened, the lamp contact can only close the lamp circuit when the preparatory contact is closed. In this way the intervals can be changed in steps from 20 to 600 seconds (*i.e.*, 20, 40, 60, 100, 200, 400, 600 seconds) by merely reducing the number of pegs in the second disk.

The different ratios of acceleration during *projection*, resulting from the different ratios of retarded *taking* of the pictures are computed in Table 1. It also contains the projection time of an actual event taking normally 12 hours and recorded with different ratios of acceleration.

TABLE 1

Interval between two pictures	Ratio of acceleration when projected with the physiologically adequate speed of 16 frames per second	A process of 12 hours duration is projected in:	Number of pictures in one hour
1 sec.	1: 16	45 min.	3600
2 sec.	1: 32	22 min. 30 sec.	1800
4 sec.	1: 64	11 min. 15 sec.	900
5 sec.	1: 80	9 min.	720
10 sec.	1: 160	4 min. 30 sec.	360
20 sec.	1: 320	2 min. 15 sec.	180
40 sec.	1: 640	1 min. 7, 5 sec.	90
1 min.	1: 960	45 sec.	60
1 min. 40 sec.	1: 1600	27 sec.	36
2 min.	1: 1920	22, 5 sec.	30
3 min. 20 sec.	1: 3200	13, 5 sec.	18
10 min.	1: 9600	4, 5 sec.	6

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NOTE ON KEEPING LIVE FROGS FOR EXPERIMENTAL PURPOSES

SINCE the common experience of having frogs die in tanks, particularly in warm weather, is very disconcerting, it was thought worth while to insert in SCIENCE a note on our experience in storing these animals in a little electric refrigerator.

We have been able to keep a gross of frogs, in a hardware cloth box which fits in the bottom of our T. V. A. refrigerator, for a month with only three or four fatalities. They are dormant in the box (10° C.), giving only an occasional muffled croak as the machinery starts. When warmed, however, to room temperature, they become normally active with startling suddenness. Certain shipments, badly infected with "red leg," lasted surprisingly well in the refrigerator.

The only care we have given the animals has been to pick them over every day and to wet them with tap water.

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SPECIAL ARTICLES

A LETHAL MUTATION IN THE RABBIT WITH STIGMATA OF AN ACRO-MEGALIC DISORDER

A DWARF mutation in the rabbit was described in a previous paper.[1] In that instance the symptom-complex of affected animals suggested a diminished function of the growth-promoting hormone of the pituitary combined with basophilic over-activity and secondary disturbances of other endocrine glands. A contrasting abnormality of hereditary origin has also been found in the rabbit. When this affection was first seen, it was studied as a condition probably arising from a disturbance of thyroid function, and therapeutic tests, which were inconclusive, seemed to lend some support to this assumption. But it was later pointed out to us by Dr. H. M. Evans that the distinctive feature of the condition corresponded closely with the cutaneous overgrowth which Stockard[2] first recognized as a characteristic manifestation of acromegalic disorders.

This peculiar abnormality appeared several years ago in some hybrid stock derived from an inbred line of Dutch rabbits. It was traced back to a Dutch female, and unsuccessful attempts were made to fix the character for further study. Animals presenting the abnormality in typical form were comparatively rare, and these died at an early age. The few hybrids seen were more vigorous than the pure Dutch stock, and it was assumed that in the inbred line individuals of this class were probably lost before characteristic symptoms of the condition developed. Eventually, however, a small male presenting mild but typical symptoms of the abnormality was reared by the use of a foster mother, and breeding experiments were undertaken.

The distinctive features of the abnormality usually develop toward the end of the first or second week of life. A faint redness with an edematous thickening of the skin appears over the nape of the neck, between the shoulders, at the base of the skull, behind the ears or under the chin. This spreads to the whole ventral surface of the body and is particularly noticeable about the genital and anal regions. The condition increases rapidly. In typical cases, the skin of the entire body is thrown into loose, transverse folds. It is at first reddened, thickened and edematous with a glistening surface. Subsequently, the surface of the skin becomes covered with fine white scales and then with thicker crusts, while the skin itself becomes stiff and indurated. The hair is at first normal, but its growth is disturbed and it becomes coarse, sparse and stubby. As a rule, the growth of affected animals is at first rapid, but virtually ceases within a few days after the development of typical symptoms, and the disease progresses to a lethal termination in the course of a week or ten days. Mild and atypical, or "fugitive," cases of this affection also occur, and some of these animals are viable, but few have survived to a breeding age. The chances of survival are increased when affected animals are transferred to a foster mother, and advanced cases may be arrested by this form of treatment.

This abnormality occurs in animals of all sizes (birth weights), but in most instances the animals presenting these symptoms are exceptionally large and well nourished at the time of onset, while the small and wizened appearance of others first suggested the idea of a cretinoid abnormality, and in the end all seriously affected animals present this appearance. The bones have not been studied in detail, but skeletal overgrowth does not occur in all animals; some are large, others are small, and there is additional evidence that cutaneous and skeletal changes are to some extent separable and that one may occur independent of the other.

Breeding experiments based largely on the small Dutch male mentioned above have shown that the F_1 progeny from unrelated females is essentially normal. So far, attempts to reproduce the character in an F_2 generation, from animals obtained in this manner, have been unsuccessful. Only a few F_1 males have been tested, but none of these has transmitted the character. Still when certain F_1 females are back crossed to their male parent, typical cases of abnormality appear, while others, on repeated tests, have produced only normal young. Matings between the male referred to and F_1 daughters derived from unrelated females and known to be transmitters have given 15 typically affected and 44 normal young, exclusive of a few cases of mild or atypical abnormality, which is a close approximation to a 3 : 1 ratio.

These tests show that the male in question is heterozygous, despite the fact that he exhibited typical symptoms of abnormality in early life. He was derived from a mating of parents both of which were proven transmitters and, so far, all known male transmitters have been obtained in this fashion. Results from the reciprocal cross are uncertain. Only one female presenting definite symptoms of abnormality has been raised to breeding age and, in this case, repeated matings proved to be infertile. This animal also came from pure Dutch stock and from parents

[1] H. S. N. Greene, C. K. Hu and W. H. Brown, SCIENCE, 79: 2056, 1934.

[2] C. R. Stockard, "The Physical Basis of Personality," W. W. Norton and Co., New York, 1931. Herbert M. Evans, *Jour. American Medical Association*, 101: 425, 1933.

both of which were heterozygous. In this connection, it is of interest to note that this female was also of the small or dwarf type and that the male under consideration has shown a variable fertility with periods of diminished secondary sex characters and complete sterility. It has been found, however, that matings between heterozygous females and normal males produce only normal young, as in the case of affected male × normal female. No homozygous animal of either sex has been encountered among those tested.

The condition described is unquestionably inherited, and it is evident that in the F_1 generation the character is completely recessive. On the other hand, it is known that in matings between heterozygous parents the abnormality may be expressed in heterozygous males as well as in homozygous individuals, and that the homozygous form is apparently lethal. Until this situation is cleared up, ratios of normal to affected individuals can not be interpreted with certainty.

The disease described appears to fit into the syndrome which, at present, is associated with over-activity of the growth-promoting hormone of the pituitary. The apparent disturbance of thyroid function in certain cases may likewise be attributed to a pituitary abnormality affecting the thyrotropic hormone. In this instance, however, there is some evidence of an appreciable degree of differentiation, or separation, of cutaneous and skeletal manifestations of functional disorder. But further experiments will be necessary to determine the etiology of the condition as well as the precise mode of its inheritance.

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THE MODE OF PENETRATION OF PEAR AND APPLE BLOSSOMS BY THE FIRE-BLIGHT PATHOGEN[1]

A STUDY of the mode of penetration of the fire-blight pathogen into pear and apple blossoms has revealed some facts which seemingly are significant from a point of view of possible control measures. Histological studies of both natural and artificial infections, which will be fully illustrated by photomicrographs and drawings in a later paper, reveal the following.

There is a well-defined cuticle covering the nectarial region of both pear and apple blossoms.[2]

[1] Research Paper 352 Journal Series, University of Arkansas.

[2] Professor L. H. MacDaniels, of Cornell University, has confirmed and amplified the writer's findings concerning cuticular covering of nectarial regions of pear and apple blossoms.

The nectar, instead of exuding from naked cells, as commonly assumed, passes out through stoma-like openings, the openings seemingly being regulated by guard cells, as in true stomata. For these nectar-exuding structures the writer proposes, for convenience, the name "nectarthodes." They have previously been noted in nectarial regions of other blossoms by various authors.

In the nectarial region of pears and apples, the fire-blight pathogen gains entrance into the interior by means of these nectarthodes, though entrance through these is apparently not nearly as common on apple blossoms as on pear. The reason for this difference rests essentially in the narrow, elongated, tightly covered calyx cup, characteristic of apple blossoms during nectar flow, contrasted with the broad, open and shallow calyx cup, characteristic of pear blossoms.

In addition to penetration through nectarthodes, *Erwinia amylovora* has no difficulty penetrating the following: First, the stigmatic surfaces of both pear and apple gynoecia, the large glandular naked cells of these surfaces making penetration under suitable conditions a relatively simple matter. The manner of such penetration will be fully illustrated elsewhere. Second, the locules of the anthers, with a seeming passage into filaments. The passage from anther to filament has not been fully confirmed.

These common methods of penetration of pear and apple blossoms are additional to those which the writer and other investigators have previously reported, and which include penetration through stomata of calyx lobes and outer receptacle walls, as well as through petals.

If floral infections of apples depended entirely on nectarial penetration, what chance would there be of controlling blossom infection by depositing a germicidal spray with ordinary spray-equipment in such tightly covered plant parts?

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